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THESIS

**A WIRELESS LOCAL AREA NETWORK COMMAND AND
CONTROL SYSTEM FOR EXPLOSIVE ORDNANCE
DISPOSAL INCIDENT RESPONSE**

by

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September 2001

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SYSTEM FOR EXPLOSIVE ORDNANCE DISPOSAL INCIDENT RESPONSE**

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B.S., University of Washington, 1991

Submitted in partial fulfillment of the
requirements for the degree of

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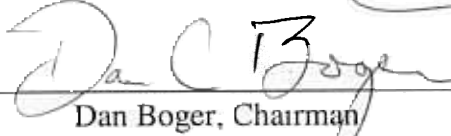
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ABSTRACT

Navy Explosive Ordnance Disposal (EOD) teams currently use a hardwire intercom system for command and control when responding to EOD incidents. This system is archaic, awkward, and cumbersome. A modern information system will greatly improve safety and efficiency during EOD operations.

This thesis presents a lightweight, ruggedized, field portable, wireless local area network (LAN) designed for use by U.S. Navy EOD teams during EOD incident responses. The information system provides a voice, video, and data link between the command post and the down range response team, thus offering significant improvements over current EOD command and control methods.

The system components are commercial off the shelf technology (COTS) and are chosen based on specification analysis for performance, reliability, availability and cost. Calculations for traffic flow analysis, electromagnetic radiation (EMR) levels, and theoretical range are provided.

Based on the new capabilities provided by the system, revised response tactics for EOD teams are proposed that allow multiple render safe procedures to be conducted simultaneously by a single team, thus providing a quantum leap in efficiency.

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I. INTRODUCTION

A. MOTIVATION

The modern advances in wireless technology can provide communication capabilities that would have been quite impossible only a few years ago. Now that private industry has overcome a majority of the technical hurdles, a challenge for the Navy is to develop applications that exploit these new capabilities.

One such application of wireless technology is to provide Navy Explosive Ordnance Disposal (EOD) teams with a modern command and control system to use during EOD incident responses. The present system has several limitations and disadvantages that hinder EOD operations. It is an archaic hardwire intercom that dates back to World War II, and has remained unchanged for decades. It is awkward and time consuming to deploy. It only supports half duplex voice communication, and it has a high failure rate because the wire is fragile and frequently breaks in field conditions.

Hand held radios are used as a secondary form of communication. This method has its own drawbacks. The downrange transmitter must use reduced power settings because electrically initiated ordnance, especially in a damaged condition, is sensitive to electromagnetic radiation (EMR). This severely limits the useful range of the radio. Also the command post is normally not within line of sight of the incident, thus further limiting the radios effectiveness. Many EOD procedures are classified, which requires cryptologic equipment to encrypt radio communication.

Clearly there is a need to apply modern wireless network technology to this problem. The ability to speak, send documents, pictures, and video, securely between the command post and the incident site will offer a vast improvement over the current

capabilities. In addition, the ability to do remote sensing and monitoring, and conduct remote procedures using robotics, offers exciting possibilities for the future.

B. OBJECTIVES

The primary objective of this thesis is to design a modern wireless command and control information system using available commercial off the shelf technology (COTS) that satisfies the unique and demanding requirements of Navy Explosive Ordnance Disposal teams operating in the field. The author's intent is for this document to be used as a blueprint and component guide by the EOD Technology Center to assemble a prototype system for testing and evaluation, ultimately leading to deployment in the fleet.

The design process will address several special considerations that are critical for successful development of an EOD wireless information system. One consideration is the hazard of electromagnetic radiation to ordnance (HERO) when conducting procedures on electrically initiated ordnance. Others considerations are portability, survivability and security in field conditions as well as ensuring the information system will survive in a marine environment when operating at sea from small inflatable boats.

A secondary objective is to propose organizational and tactics changes that will capitalize on the new system's capabilities, allowing EOD operations to be conducted significantly faster with greater safety and efficiency.

C. SCOPE

This thesis will define the physical, operational, and security requirements for an EOD wireless command and control system. It will then identify the optimum network architecture, hardware configuration, peripherals, and software components that will satisfy the defined requirements.

In order to determine the optimum system configuration, manufactures specifications will be compared for each component with selection based on performance, reliability, availability and cost. The complete system configuration will be documented and modeled. The system limitations and vulnerabilities will then be analyzed and discussed.

The final portion of the thesis will be a proposal to develop a new organizational structure for EOD teams along with revised response tactics that fully exploit the capabilities of the wireless command and control system.

D. METHODOLOGY

The research methodology used for this thesis will consist of the following steps:

- Conduct a literature search of books, magazine articles, electronic information systems and other library information resources.
- Identify the system requirements.
- Determine the optimum local area network architecture based on system requirements.
- Conduct a thorough review of hardware requirements, software requirements, compatibility issues, and standards.
- Identify the optimum hardware configuration based on specification review and cost analysis.
- Identify the optimum software configuration based on specification review and cost analysis.
- Document the system configuration.
- Determine the system limitations and vulnerabilities.
- Evaluate the benefits and costs of implementing the system.
- Define new operation EOD tactics to be used with the system.

E. ORGANIZATION OF STUDY

This thesis is divided into 9 chapters and 1 appendix. Chapter II gives background information on EOD operations and information system design. Chapter III defines the

physical, operational, and security requirements for the system. Chapter IV describes the network design and analysis. Chapter V covers the hardware selection including network, computer, and peripherals. Chapter VI describes the required operating and application software for the system. Chapter VII provides the complete system configuration including parameters and modes of operation, system limitations and vulnerabilities, and system documentation. Chapter VIII describes the system costs. Chapter IX provides conclusions and recommendations including revised EOD response tactics.

II. BACKGROUND

A. EXPLOSIVE ORDNANCE DISPOSAL OPERATIONS

Navy EOD teams operate in extreme field conditions, from arctic snows, to equatorial jungles, to desert wastes, and to the depths of the world's seas. Some teams are shore based and support installations or geographic regions while others deploy with battle groups to support fleet operations. Their mission is to detect, recover, identify, evaluate, render safe, and dispose of unexploded ordnance that poses a threat to people, material, installations, ships, aircraft, and operations. The teams are comprised of 5 to 10 highly trained Navy divers that are experts in explosive ordnance and demolition procedures.

Navy EOD has the capability to deal with the full spectrum of explosive ordnance, from small arms ammunition to weapons of mass destruction (WMD). Because the possible scenarios are almost limitless, the teams are trained to respond based on ordnance type. These include Air, Ground, Underwater, Improvised Explosive Devices (IEDs), Chemical, Biological, and Nuclear. These categories help determine what type of tools and equipment will be used to eliminate the hazard. Although there are many variables that determine how and where the teams will operate, the ability to effectively communicate is consistent with every response.

When Explosive Ordnance Disposal teams respond to an EOD incident on land, they are required to establish a communication system between the command post and the incident site. The command post must be outside the blast and fragmentation radius of the explosive item(s). The distance between the command post and the incident site can be up to 5 miles away depending on the explosive weight and type of ordnance

involved. Another requirement is that communications must be maintained at all times when an EOD technician is down range. If contact between the command post and the incident site is lost, all work must stop until communications are re-established.

The limitations of the present system force the EOD technician working downrange to travel back and forth between the command post and the incident site several times. First, the EOD technician moves to within visual range of the item and performs a long-range reconnaissance. He then returns to the command post to make an initial identification using a laptop computer with an electronic technical library on compact disc. After determining the required safety precautions for the item, the EOD technician goes back down range to do a detailed close range reconnaissance including taking measurements and pictures. He then comes back to the command post to use the technical library to make a positive identification and develop a set of render safe procedures (RSPs). Once this step is completed, the EOD technician travels back down range to perform the RSP. As each step is completed, the down range technician reports to the command post, which monitors the progress and keeps a written log of events. While the down range EOD technician is working, a second EOD technician acts as a forward observer and watches within visual range so that if a premature detonation occurs, the team will know exactly what the down range technician was doing when the accident occurred.

When EOD teams operate at sea, they use small inflatable boats that are supported by the battle group or a shore facility. During diving and mine countermeasure operations it is essential to maintain a communication link with the operational commander. This is the only way to request medical evacuation in the event of a diving accident or to

transmit and receive situation reports. The current method uses high frequency (HF) and very high frequency (VHF) radios. The limitations of this method are relatively short ranges for the VHF radios, complications with encryption, and no data or video capability.

The requirement to maintain a communication link is vital to all EOD operations no matter what the environment or scenario. In every circumstance, a reliable, secure, wireless network connection will enable measurable improvements in speed, efficiency, and safety.

B. NETWORK DESIGN

In order to design an information system that supports the users needs, a logical process must be followed. In James McCabe's book "*Practical Computer Network Analysis and Design*" [1] he presents a systems approach to network design.

According to McCabe, the critical steps in creating an effective network are requirements analysis and flow analysis. The output from the analysis process is then used in the design of the logical and physical network. Figure 2.1 illustrates the network analysis process while Figure 2.2 illustrates the Network design process.

McCabe's models of analysis and design will be used whenever applicable in the development of the EOD wireless command and control system.

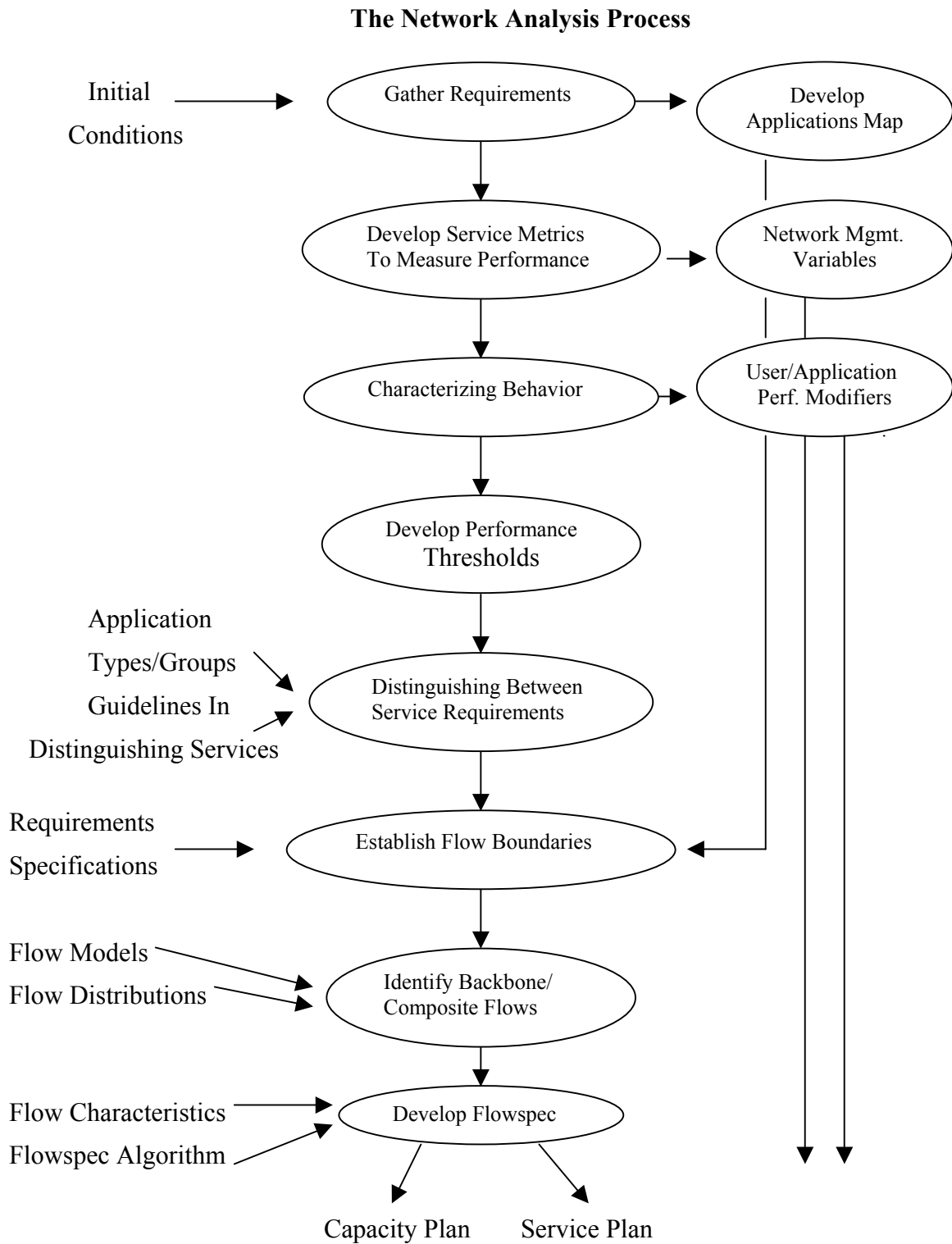
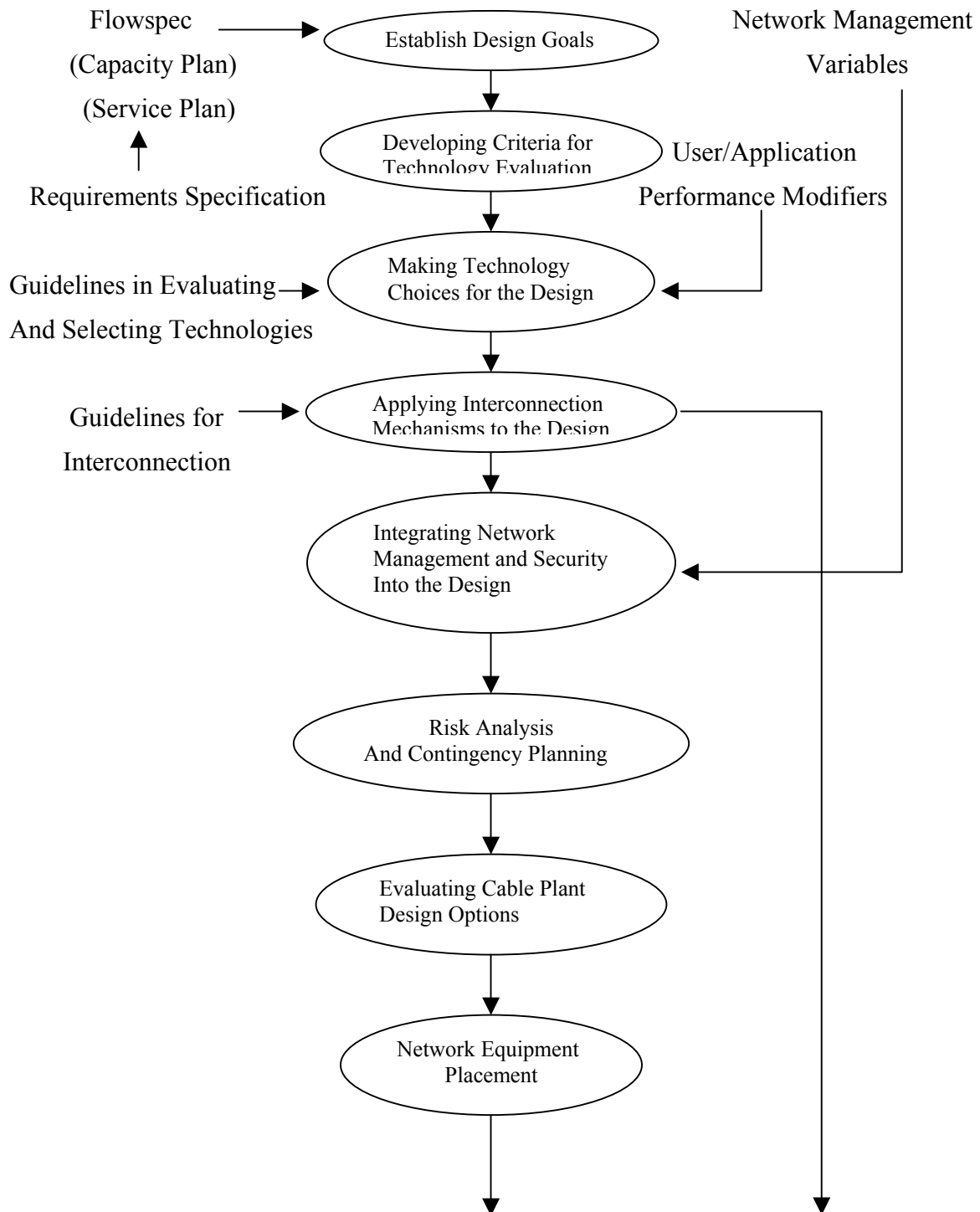


Figure 2.1 The Network Analysis Process. From McCabe 1998

The Network Design Process



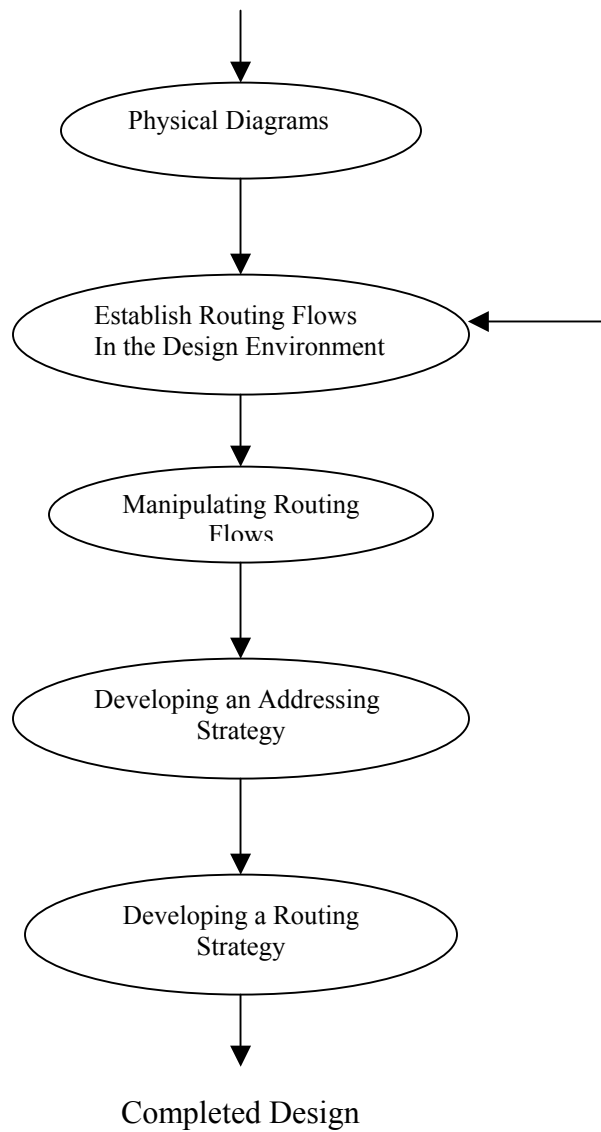


Figure 2.2 The Network Design Process. From McCabe 1998

III. REQUIREMENTS

A. APPLICATION REQUIREMENTS

McCabe describes application requirements based on capacity, reliability, and delay. He organizes applications by groups, types, performance requirements, and locations.

Groups are applications with similar performance characteristics. The types of applications are categorized as mission critical, controlled rate, and real time. Application performance is characterized as high or low, based on thresholds for delay. The two categories for delay are real-time and non-real-time. Non-real-time is further divided into interactive and asynchronous. Real-time, defined here as when delay is not perceptible to the user, is considered high performance while asynchronous such as email is considered low performance.

To achieve the desired results, the EOD command and control system will require a combination of real time and controlled rate applications. All the applications will be mission critical. The groups will consist of tele-service applications, visualization applications, cooperative computing applications and web based applications.

APPLICATION GROUPS	MISSION CRITICAL	REAL-TIME	CONTROLLED RATE	PERFORMANCE
Tele-Service	X	X		High
Command & Control	X	X		High
Visualization	X		X	High
Cooperative Computing	X		X	High
Web Access	X		X	Low

Table 3.1 Application Requirements

The tele-service application is needed to permit communication between the command post and the downrange site. It will provide real-time teleconference service.

The command and control applications allow remote sensing and monitoring of the downrange site. These applications may also be used to control robots that will perform remote procedures at some point in the future.

The visualization application displays technical drawings, documents, and pictures from the electronic technical library. The downrange EOD technician will use this application to identify and perform procedures on ordnance.

The cooperative computing applications will perform mission specific tasks such as calculating blast and fragmentation distances, down wind hazard areas during chemical, biological, and nuclear problems, and safe stay times for radiological environments.

Web access applications will permit images to be e-mailed, the use of live-chat sessions as a backup communication link, and for remote Internet access if required.

B. USER REQUIREMENTS

A primary design goal for the EOD command and control network is to use commercial off the shelf (COTS) technology to meet the system requirements. There are several advantages to not using Military Specification (MIL-SPEC) components. First, the system cost will be significantly less by avoiding the MIL-SPEC process. Second, the time to develop, build, and maintain the system is greatly reduced by using immediately available parts. Lastly, the system is easier and cheaper to update as new technology provides better solutions.

Since the formal MIL-SPEC process is not being used to define the requirements, special attention must be paid when identifying the system's unique military requirements. In order to effectively articulate all the user requirements, two sets of requirements will be generated. The first set will be military specific user requirements; the second will be general user requirements common to all network designs.

1. Military User Requirements

The military requirements are used to identify the special capabilities needed by the system to perform its military mission. The following are the EOD specific military requirements:

- Light weight – the downrange components need to weigh less than 50 lbs, the command post components need to weigh less than 100 lbs so that the equipment can be easily carried by one person downrange and two people at the command post.
- Mobile – the system must be easy to transport and quick to deploy. It needs to be set up and operational in less than 10 minutes.
- Man portable – The downrange components must fit in two suitcase sized storage containers so that one person can carry the equipment in a single trip.
- Weather resistant – the system must be able to operate in extreme conditions including dust, sand, mud, rain, snow, and from small inflatable boats in marine environments.
- Shock resistant – the system must be able to survive the rigors of field conditions. It needs to survive a 3-foot drop inside the storage containers.
- Contaminated Environments – the downrange components must be able to be decontaminated after operating in a chemical, biological, or nuclear environment.
- Secure – the system must be able to provide confidentiality and authenticity while transmitting secret documents as well as during voice and video communication.
- Stable – the EOD command and control network is mission critical and must be resistant to system crashes and lockups to the greatest extent possible.

- Endurance – the system must operate for a period of at least 8 hours without requiring battery recharging or replacement, which will permit most missions to be completed without interruption.
- HERO safe – the radiated power output at the downrange site must be less than 1 Watt at 10 feet or 5 Watts at 25 so that system will not cause electrically initiated explosives to detonate.
- Effective range – the effective range of the wireless link must be a minimum of 5 miles, to allow the command post to remain outside the maximum fragmentation radius.
- Positional Awareness – the network requires Global Positioning System input to determine location and separation distance between command post and downrange site and so that it can be used while navigating to the incident site.

MILITARY USER REQUIREMENTS	CRITERIA
Light weight	Downrange 50 lbs, Command Post 100 lbs
Mobile	Setup time less than 10 minutes
Man portable	Two suitcase sized containers maximum for downrange components.
Weather resistant	Ability to operate and survive in field and marine environments.
Shock resistant	Survive 3 ft drop in the storage containers.
Contaminated environment	Downrange components must operate in Chem, Nuke, and Bio environment.
Secure	Satisfy military requirements to transmit secret documents, voice and video
Stable	System operates without application or device conflicts. Crash resistant
Endurance	Operate continuously for a minimum of 8 hours without battery recharge or replacement.
HERO compliant	Radiated power output downrange less than 1 Watt at 10 Ft and 5Watts at 25 Ft
Effective Range	Minimum range of wireless link is 5 miles.
Positional awareness	System requires GPS input to determine position and separation distance.

Table 3.2 Military User Requirements

2. General User Requirements

The general user requirements characterize the service and capacity metrics that will be needed in the design phase to ensure the network achieves the desired performance levels.

McCabe describes the general requirements of the user to be:

- Timeliness – a requirement that the user be able to access, transfer, or modify information within a tolerable time frame.
- Interactivity – is similar to timeliness, but focuses on a response time from the system (and network).
- Reliability – is a requirement for consistently available service.
- Quality – refers to the quality of the presentation to the user.
- Adaptability – is the ability of the system to adapt to the user's changing needs.
- Security – is a requirement to guarantee the integrity of the user's information and physical resources, as well as access to the users and systems resources.
- Affordability – what the user can afford to purchase.

The timeliness requirement for the EOD wireless command and control system will be described as best effort. This means that the network will operate at its maximum capacity for the given conditions. There is no specific performance guarantee for any operation.

The maximum value for interactivity will be specified as 30ms. This value was chosen because it is the threshold that users can aurally perceive delay during communication.

Reliability is a critical requirement for this system. It is essential that the network be as reliable as possible without resorting to parallel components. The use of parallel components is not practical in this case because of the increased weight and the additional cost. The minimum value for reliability will be 99%. This equates to less than five minutes of down time in an eight-hour period.

The requirement for quality is based on users being able to clearly see and communicate with each other. By providing adequate bandwidth, applications that use voice and video will achieve high levels of quality.

Adaptability is another critical requirement. There are two types, mission adaptability, and lifecycle upgrade. The system will have to operate effectively in a variety of environments to meet its military mission requirements. It also needs to be an open system that easily incorporates new components as technology evolves.

Security as defined here is not the same as the military definition used to describe the protection of classified information from disclosure. In this case, it is the authenticity and integrity of the data. The network needs to be resistant to hacking and jamming.

Affordability for this system should be measured by the value of its capabilities. The question is how much is it worth for what it can do? A reasonable figure would be \$45,000 to \$50,000 for each EOD team's initial procurement of a complete system.

GENERAL USER REQUIREMENTS	CRITERIA
Timeliness	Best effort
Interactivity	30 ms maximum
Reliability	99%
Quality	High quality voice and video
Adaptability	Open architecture
Security	Hacking and jamming resistant
Affordability	\$45,000 to \$50,000 initial procurement

Table 3.3 General User Requirements

C. HOST REQUIREMENTS

McCabe has grouped hosts into three categories: generic computing devices, servers, and specialized equipment. The EOD network has requirements for all three.

The performance characteristics of the hosts are described by storage performance, processor performance, memory performance, bus performance, operating system performance, and device driver performance.

The location of the hosts is another critical requirement in network design. Since the EOD command and control system will be a mobile wireless system, the locations will be variable. The limiting factor for location is the range of the wireless link between the command post and the downrange site.

All host equipment needs to be hardened for field use, including requirements to be weather and shock resistant. A laptop computer in the command post will function as a server, while each down range site will have a laptop computer classified as a generic computing device. The laptop computers need to have high performance processors with a clock speed of at least 500-MHz. The random access memory needs to be at least 128 Megabytes. The hard drive needs to be a removable type with a storage capacity of at

least 20 Gigabytes. The laptops will also need USB ports, PCMCIA slots, and network interface cards.

The peripheral equipment requirements include a need for Universal Serial Bus (USB) hubs, video cameras, speakers and microphones, Global Positioning System (GPS) receivers, personal digital assistants (PDA) and printers.

The specialized equipment requirement is for sensors and monitors as well as robotics to conduct remote procedures. Although these methods and capabilities are not currently employed, they need to be planned for future expansion.

HOST	CATAGORY	CRITERIA
Command post laptop computer	Server	Current generation processor hardened to MIL STD 810D
Downrange laptop computer	Generic computing device	Current generation processor hardened to MIL STD 810D
Monitors	Specialized equipment	Future capability – Remote Monitoring
Sensors	Specialized equipment	Future capability – Remote Sensing
Robotics	Specialized equipment	Future capability – Remote Procedures

Table 3.4 Host Requirements

D. NETWORK REQUIREMENTS

There is no legacy network that requires interface considerations. The EOD network will be a stand-alone system, which can be described as best effort since there are no means to allocate resources to specific applications in order to provide performance guarantees. Because the system is small with only a few applications, the

simple solution is to overprovision the network so that applications are not competing for resources. This will allow individual applications to operate within specified delay tolerances and meet network performance requirements.

Based on the requirement to avoid application resource conflicts, the minimum acceptable bandwidth for the EOD network is 1.5 Megabytes per second.

The network must support the standard Internet protocols. It must also provide a robust wireless link over a minimum distance of 5 miles that is resistant to hacking and jamming.

NETWORK REQUIREMENTS	CRITERIA
Capacity	1.5 Mbps minimum
Network Protocols	TCP/IP, UDP, SNMP, TFTP
Wireless Range	5 miles minimum

Table 3.5 Network Requirements

E. SUMMARY

This chapter has outlined all the requirements that must be met so that the EOD wireless command and control system will achieve its design goals. The result of meeting these goals will be a wireless link between the command post and incident site that can securely transmit voice, video, and data over a distance of 5 miles at a rate of 1.5 Mbps for a period of 8 hours in harsh field conditions.

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IV. NETWORK ANALYSIS AND DESIGN

A. FLOW

The ultimate goal of flow analysis is to produce a flow specification or flowspec that will be used in capacity planning for best effort and service planning for specified service. According to McCabe, flow analysis is where services and performance characteristics are transformed into specifications that can be directly applied to technology and protocol choices. The steps to produce a flowspec include identifying data sources and sinks, selecting flow models, and mapping flows. The final step is to use the flowspec algorithm to determine the required capacity, reliability, and delay values that will satisfy the network requirements.

The first step of identifying data sources and sinks is a trivial process for the EOD wireless command and control system since there is limited number of nodes and applications. Data will be provided and requested at both the command post and the incident site. In this case each node is both a source and a sink.

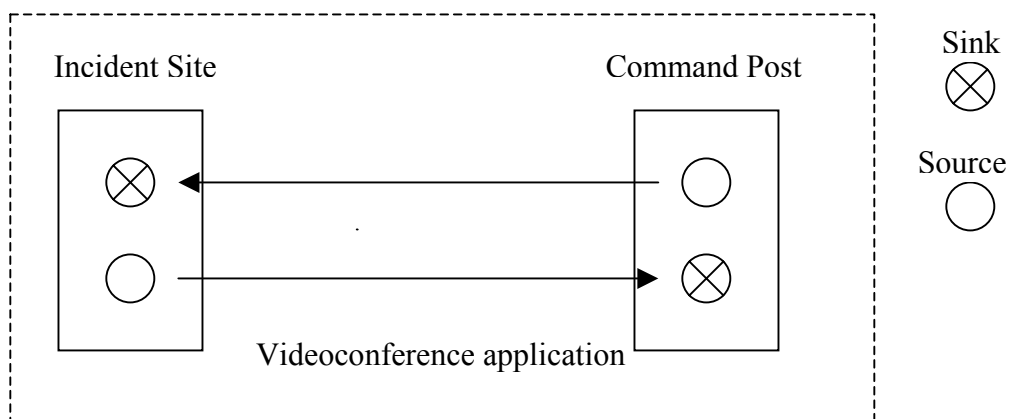


Figure 4.1 Data Sources and Sinks

The next step is to identify the flow models. The EOD wireless command and control system is a simple network with flows that are best represented by the peer-to-peer and client server models. These two models describe different types of flows.

In the peer-to-peer model, flows travel without hierarchal structure symmetrically in both directions between computers.

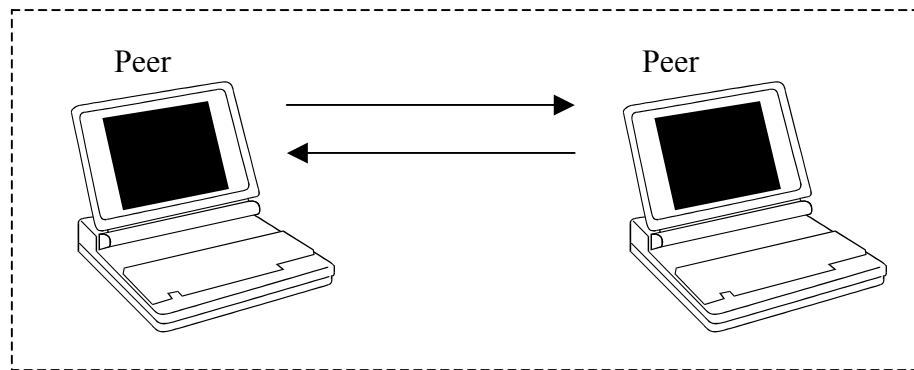


Figure 4.2 Peer-to-Peer Model

In the client server model, flows are asymmetrical in direction and follow a hierarchal structure.

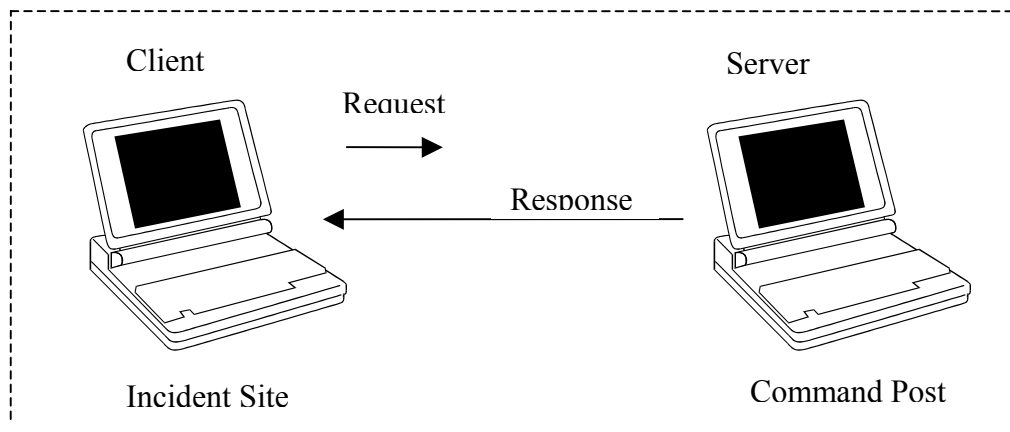


Figure 4.3 Client Server Model

These two models represent how the applications will interact across the EOD network during individual sessions. The videoconference application is an example of the peer-to-peer model, while queries to the technical library database represent the client server model.

The third step is mapping the flows. This will be accomplished by identifying the applications that create each flow, and then assigning estimated bandwidth requirements to each application. Figure 4.4 shows typical bandwidth requirements for various multi media applications.

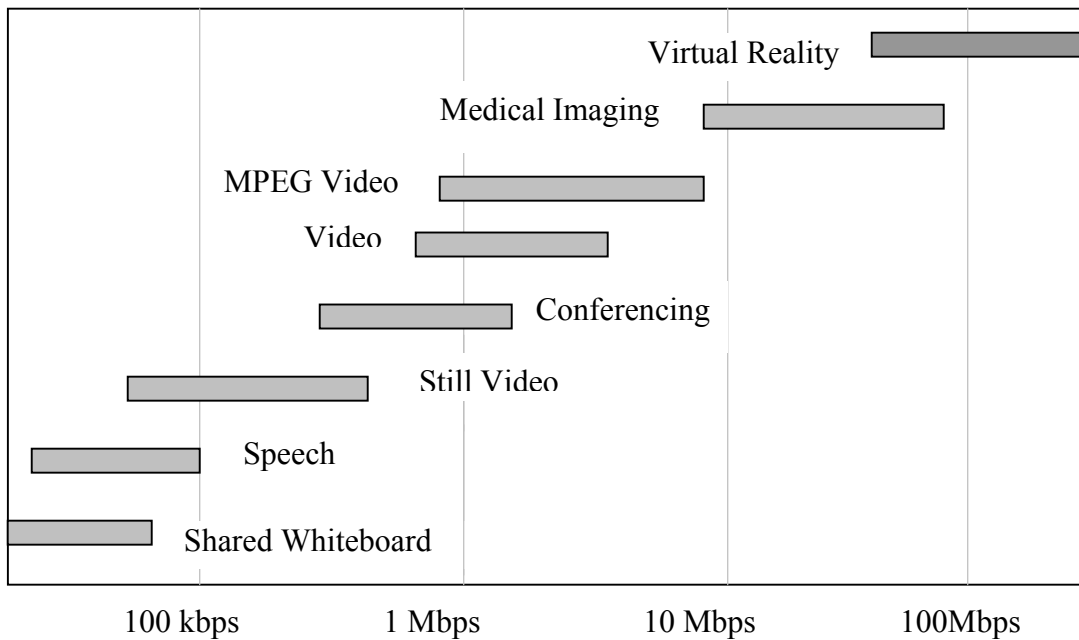


Figure 4.4 Multimedia Bandwidth Requirements After Cisco Internet Design Guide 1999

Based on the applications identified in chapter III, the following flows and their estimated bandwidth requirements are defined as:

- F1 – Videoconference between command post and incident site (600 kbps).
- F2 – Data transfer between command post and incident site (100 kbps).
- F3 – Application sharing between command post and incident site (100 kbps).
- F4 – Command and control for robotics and telemetry from sensors and monitors between command post and incident site. (600 kbps)

The final step is to use the flowspec algorithm to determine the required capacity.

A simplifying assumption of best effort service will be applied, this eliminates calculating a specified environment with delay and reliability values. The algorithm is given as:

$$\Sigma C_{BE} = F1 + F2 + F3 + Fx...$$

Using the bandwidths identified above produces the following result:

$$F1 (600 \text{ kbps}) + F2 (100 \text{ kbps}) + F3 (100 \text{ kbps}) + F4 (600 \text{ kbps}) = 1.4 \text{ Mbps}$$

This value represents the total bandwidth capacity required to support the applications that will be currently used for the EOD wireless command and control network. In reality, the capacity requirements will be less than the 1.4 Mbps because the videoconference flow (F1) and the command and control flow (F4) will not normally occur simultaneously. The F1 flow will be used when an EOD technician is working down range while the F4 flow will be used during remote procedures when no one is present.

Based on these results, the network design capacity of 1.5 Mbps will ensure each application can operate at its maximum capacity without bandwidth restriction.

B. ARCHITECTURE

To achieve the design requirements of the EOD wireless command and control network, the architecture must provide a wireless point-to-point or point-to-multipoint connection that will allow two or more laptop computers to communicate with each other at a minimum data rate of 1.5 Mbps.

A search of the literature reveals that there are many local area network (LAN) topologies to choose from. Douglas Comer's book "*Computer Networks and Internets*" [2] describes the three most popular LAN topologies as bus, ring, and star. The names describe the basic shape of the network wiring. Since these configurations are intended for fixed wired installations, they will not satisfy the requirements of the EOD wireless command and control network.

The traditional wireless LAN architecture is based on low power, close range, radio frequency (RF) access points that create cells of connectivity. This arrangement is also not adequate for the EOD network because of limited range and low bandwidth.

There are several wireless broadband technologies that use cell based or mesh topologies to create mobile networks. These are designed to provide enterprise level wireless ISP service and have several disadvantages that preclude them from serious consideration. They include high cost, complicated hardware configurations, lack of portability, and licensing requirements.

The optimum solution is a hybrid Ethernet using a wireless bridge. This arrangement has all the advantages of the Ethernet bus architecture while providing the simplicity, mobility, and range of a wireless system. Steven Tripp demonstrated the

potential of this topology in a 1999 Naval Postgraduate School Thesis titled “*An airborne high data rate and low cost digital communications network using commercial off the shelf wireless Local Area Network components*”. [3] During his research, he was able to email images from an aircraft over a wireless Ethernet link at a distance greater than 40 miles. Figure 4.5 illustrates the hybrid Ethernet wireless bridge solution.

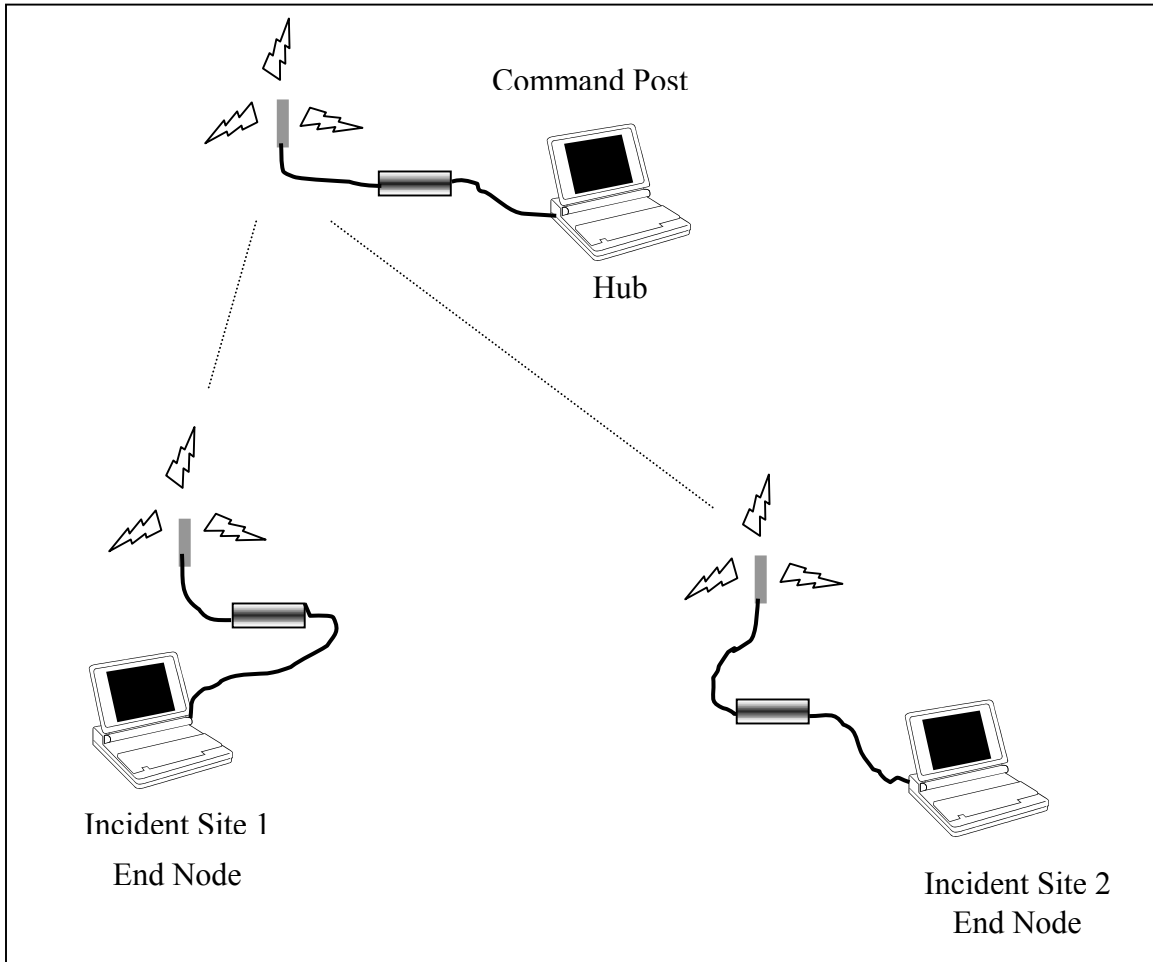


Figure 4.5 Hybrid Wireless Ethernet Architecture

This system follows the network design edict of bridge when you can, route when you must. The wireless bridge will allow point-to-point or point-to-multipoint

connections that are seamless and invisible to the users. It is also the simplest configuration to setup in field conditions, requiring only a few cable connections.

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V. HARDWARE ANALYSIS AND SELECTION

A. INTRODUCTION

The hardware analysis will identify the components needed to construct the EOD wireless network. This includes network hardware, computer hardware, peripherals, and power supplies. Procurement specifications are provided for the major components and recommendations are made for each component based on performance, reliability, availability and cost. The goal is to obtain the most robust and reliable integrated hardware configuration.

B. NETWORK HARDWARE

1. Network Hardware Procurement Specifications

The product requirements for the network hardware are:

- Must operate in the non licensed 2.4 GHz band
- Must not use the 802.11b standard
- Must support the Vine topology
- Must consume less than 5 watts of power
- Must weigh less than 2.5 pounds
- Must be environmentally sealed
- Must have a 10/100-base T Ethernet port
- Must provide a data rate of 11 Mbps
- Must have a peak output power of 23 dB
- Must be priced less than \$ 1,700

2. Network Hardware Recommendation

One choice for network hardware is the UC Wireless VIP 110-24 spread spectrum radio transceiver. This device will provide an 11 Mbps link over a distance greater than 12 miles. It has several advantages over peer competitors including being the most rugged and the simplest to use.

It uses a proprietary network architecture called VINE. This tree topology allows point-to-point or point-to-multipoint connections that can be expanded one node at a time as requirements increase. This arrangement allows the VIP 110-24 to act as a hub, a repeater, or an endpoint in the network.



Figure 5.1 UC Wireless VIP 110-24

The company's product description is as follows:

“The VIP 110-24 is a Spread Spectrum transceiver that implements the VINE protocol. The radio includes a 10/100-Base T Ethernet port for connection to the Local Area Network (LAN). The radios can be set to operate in either Bridge mode or Router mode. In bridge mode, any station connected to the LAN can see any other station connected to all the other LANs at the remote sites. No special configuration of the user stations is necessary, as each of them believes that there is just one Ethernet.

The VIP 110-24 is a Spread Spectrum radio operating in the “Industrial Scientific and Medical” (ISM) band from 2.400GHz to 2.4835 GHz. Spread Spectrum technology allows operation without a license with an output power of up to 23 dBm at speeds up to 11 Mbps (mega-bits per second).

With exception of the indoor power inserter, all of the VIP 110-24 electronics are included in a watertight outdoor unit enclosure. A single CAT 5 cable carries the Ethernet data and DC power to the outdoor enclosure.”

Appendix A is the users manual for the VIP 110-24. Table 5.1 provides the manufacturer's product specifications.

RF Specifications	
RF Frequency Band	2.410 GHz to 2.470 GHz (center frequencies)
RF Signal Bandwidth(-20 dBc)	18 MHz
RF Channels	31 (4 non-overlapping)
Transmitter Output Power	0 to 23 dBm (programmable)
Modulation Type	direct sequence spread spectrum
RF Data Rates (one way)	1, 2, 5.5, 11 Mbps
Receiver Sensitivity (10 ⁻⁶ BER)	-89 dBm (@ 1 Mbps) -86 dBm (@ 2 Mbps) -84 dBm (@ 5.5 Mbps) -81 dBm (@ 11 Mbps)
Data Interfaces	
Auxiliary Port	RS-232
Ethernet Port	10/100 BaseT
Power Requirements	
Input Voltage (Outdoor Unit)	+12 to +24 Volts DC
Input Voltage (AC)	110 VAC or 220 VAC
Power Consumption	less than 5 Watts
Environment	
Temperature	-35 to +65 Degrees C
Max. Humidity	90% non-condensing
Mechanical:	
Dimensions	3.14" wide x 2.24" high x 4.92" deep (79mm W x 56 H x 125 D)
Weight	2.4 lbs. (1.1 Kg).

Table 5.1 VIP 110-24 Specifications

3. Link Budget, Range and Power Output Calculations

This section will use the manufactures specifications and users guide for the VIP 110-24 to calculate the free path loss, the effective radiated power, and the receiver signal strength. These results will be used to determine the link margin, the range and the bandwidth limit. The final results will show the operational limits of the wireless link and help determine the best choice for antennas.

The VIP 110-24 users manual recommends a link margin of 20 db to ensure that a reliable link is maintained. A link margin of 5 dB is considered the minimum to maintain

a link. A link margin of 10 dB will be considered acceptable for the EOD wireless command and control network. This lower link margin will permit greater flexibility when selecting antennas. The semi parabolic antenna has a gain of 24 dB but is very sensitive directionally. It is also physically the largest and most vulnerable in field conditions. The Yagi antenna has a 17 dB gain and is much less sensitive to direction. It is also smaller, lighter, and much more rugged making it the preferred antenna for the downrange site. The 9 dB omni directional antenna must be used at the command post, so that the command post transceiver can function as the hub.

The users manual for the VIP 110-24 provides the equations need to calculate the free space path loss, the effective radiated power (ERP), the receiver signal strength (RSS), and the link margin. [4] The free space path loss calculates the signal loss based on the distance the signal is transmitted. The equation is given as:

$$-L_p = C + 20\log(D) + 20\log(F)$$

Where (for U.S. Units):

$-L_p$ = loss in dB

$C = 36.6$

D = path length in miles

F = frequency in MHz

Table 5.2 gives the calculated free path loss (L_p) for distances from 1 to 50 miles.

Distance (Miles)	Path loss @ 2.4 GHz (dB)	Distance (Miles)	Path loss @ 2.4 GHz (dB)
1	-104	12	- 126
2	-110	13	- 126
3	- 114	14	- 127
4	- 116	15	- 128
5	- 118	20	- 130
6	- 120	25	- 132
7	- 121	30	- 134
8	- 122	35	- 135
9	- 123	40	- 136
10	- 124	45	- 137
11	- 125	50	- 138

Table 5.2 Free Space Path Losses

The effective radiated power (ERP) at the transmitting antenna is the sum of the transmitter power plus the antenna gain minus cable loss. The equation is given as:

$$P_t = T_p + G_r - C_l$$

Where:

P_t = output power from the transmit antenna

T_p = the power from the transmitter

G_r = the antenna gain

C_l = cable loss

The VIP 110-24 can use three different antennas. The ERP in Table 5.3 was calculated using the maximum transmitter power of 23 dB, a 2 dB loss from the cable and the gain from each type of antenna.

Antena type	UC Model Number	Gain	ERP
Omni-directional	OA2.4 -9	9 dBi	30 dB
Yagi	DA2.4-17	17 dBi	38 dB
Semi-Parabolic	DA2.4 -24	24 dBi	45 db

Table 5.3 Antenna Effective Radiated Power

The next calculation yields the receiver signal loss (RSS). This value is needed to determine the link margin, range and expected bandwidth. The equation is given as:

$$RSS = P_t - L_p + G_r$$

Where:

RSS = receiver signal strength

P_t = output power from the transmit antenna

L_p = path loss

G_r = gain of receiver antenna

The link margin is calculated by subtracting the radio sensitivity (found in the VIP 110-24 specifications) from the RSS.

Table 5.4 shows link margins based on different ranges and receiver sensitivities using a Yagi antenna at the down range site and an omni directional antenna at the command post.

Yagi Antenna	17 dB Gain ERP = 30 dB	1 Mbps (-89 dB)	2 Mbps (-86 dB)	5.5 Mbps (-84 dB)	11 Mbps (-81 dB)
Range in Miles	RSS Value In dB	Link Margin In dB	Link Margin In dB	Link Margin In dB	Link Margin In dB
1	-57	32	29	27	24
2	-63	26	23	21	18
3	-67	22	19	17	14
4	-69	20	17	15	12
5	-71	18	15	13	10
6	-73	16	13	11	8
7	-74	15	12	10	7
8	-75	14	11	9	6
9	-76	13	10	8	5
10	-77	12	9	7	4
11	-78	11	8	6	3
12	-79	10	7	5	2
13	-79	10	7	5	2
14	-80	9	6	4	1
15	-81	8	5	3	0

Table 5.4 Link Margins with the Yagi Antenna

The results show that the Yagi antenna can support an 11 Mbps data link for a range up to 5 miles and a 2 Mbps data link for a range up to 9 miles. These values meet all the requirements needed for the EOD wireless command and control system while maintaining a link margin of 10 dB.

Table 5.5 provides the same results for the semi parabolic antenna used downrange.

Semi Parabolic Antenna	24 dB Gain ERP = 30 dB	1 Mbps (-89 dB)	2 Mbps (-86 dB)	5.5 Mbps (-84 dB)	11 Mbps (-81 dB)
Range in Miles	RSS Value In dB	Link Margin In dB	Link Margin In dB	Link Margin In dB	Link Margin In dB
1	-50	39	36	34	31
2	-56	33	30	28	25
3	-60	29	26	24	21
4	-62	27	24	22	19
5	-64	25	22	20	17
6	-66	23	20	18	15
7	-67	22	19	17	14
8	-68	21	18	16	13
9	-69	20	17	15	12
10	-70	19	16	14	11
11	-71	18	15	13	10
12	-72	17	14	12	9
13	-72	17	14	12	9
14	-73	16	13	11	8
15	-74	15	12	10	7

Table 5.5 Link Margins with the Semi Parabolic Antenna

The semi parabolic antenna clearly provides greater link margins over longer distances than the Yagi. This antenna should be used in marginal conditions when the Yagi antenna cannot maintain a link.

4. Competing Network Products

Similar technology from Lucent and Breezecom did not meet the requirements and specifications as well as the VIP 110-24. The Lucent ROR 1000 and the Breezecom BreezeLINK are IEEE 802.11 based solutions. This technology has security vulnerabilities and larger packet overheads not found with the UC Wireless solution. They also have more restrictive environmental limitations and are not as rugged. Table 5.6 compares the competitor specifications.

Parameter	UC WIRELESS VIP 110-24	LUCENT CR 1100	BREEZENET PRO AP 10
Size (Inches)	3.2 X 2.2 X 5	7.3 X 2 X 10.2	5.1 X 3.4 X 1.35
Weight (Pounds)	2.4	3.86	.9
Temperature Limits (Degrees F)	-31 to 167	32 to 105	32 to 105
Humidity Limit (%)	90	80	95
Data Rate (Mbps)	11	11	3
Cost (Dollars)	1,598	1,379	1,395

Table 5.6 Network Hardware Comparisons

C. COMPUTER HARDWARE

1. Computer Hardware Procurement Specifications

The requirements for the computer hardware are:

- Must pass MIL-STD 810D
- Must weigh less than 10 pounds
- Must have a removable hard drive
- Must have a daylight viewable screen
- Must have a three year warranty
- Must have a base price of less than \$ 5000

2. Computer Hardware Recommendation

One choice for laptop computers is the Panasonic Toughbook 27. The selection was made by evaluating laptop computers that passed the MIL-STD 810D tests. This is the most stringent criterion used by manufactures to test laptop computers for vulnerability to shock, vibration, moisture, and temperature.

There are several manufactures that provide laptop computers that meet the standard, however the Panasonic was the least expensive, the lightest, and the only one to offer a three-year warranty. Figure 5.2 is the manufactures product description.



Figure 5.2 Panasonic Toughbook 27

The other computers that are listed in table 4.6 will meet the requirements needed by the system but they are 4 pounds heavier and only offer a one-year warranty. The prices listed are for the basic computer without memory upgrades, daylight viewable screens, and extreme cold kits. These options will add up to another 1,000 dollars onto the price while the Panasonic comes standard with these features.

Although the Toughbook 27 has the slowest processor of the group at 500 MHz, it is more than adequate for the EOD wireless command and control system. The slower processor speed may translate to a more reliable computer with longer battery duration because of lower power requirements.

Table 5.7 compares the specifications of competing ruggedized laptops.

Parameter	Argonaut R830	Panasonic Toughbook 27	Promark Pro9000	Gorilla Systems Rocky Unlimited
Size (Inches)	12.2 X 10 X 2.76	11.9 X 9.7 X 2.6	12.2 X 10 X 2.76	12.2 X 9.7 X 2.46
Weight (Pounds)	12	8	12	10.4
Processor	Pentium III 600 MHz	Pentium III 500 MHz	Pentium III 750 MHz	Pentium III 700 MHz
Memory (MB)	256	128	128	128
Hard Drive (GB)	20	20	20	20
MIL STD 810E	Yes	Yes	Yes	Yes
Cost (Dollars)	6,449	4,999	5,165	7,700

Table 5.7 Computer Comparisons

D. PERIPHERAL HARDWARE

There are several peripheral hardware components that will be used by the EOD wireless command and control system. Some of these are digital video cameras, wireless RF and IR headsets, GPS receivers, and personal digital assistants (PDAs). In the future, there will be more peripheral devices developed that will also be useful.

The easiest way to connect these devices to the computer is through the Universal Serial Bus port (USB). This port can provide data rates up to 12.5 Mbps and will support multiple devices by adding a USB hub. USB provides hot swap plug-n-play capabilities, this means the user can add and remove devices without having to reboot or change settings. The computer will identify and load the required drivers automatically as different devices are connected to the computer. 1. Digital Video Camera

The most important peripheral item is the digital video camera. This component will transmit the video images between the command post and the incident site. The

recommended camera is Logitech's Quickcam Traveler. This inexpensive camera has a built in microphone and can also be used to take up to sixty 640 X 480 high-resolution still pictures.



Figure 5.3 Logitech's Quickcam Traveler

The manufacturer's product description is as follows:

“QuickCam® Traveler™ combines the features of an Internet video camera with the freedom of a digital still camera. Plug it into your PC for Internet video – like video e-mail, video calling, live broadcasting, and even video monitoring. Then take it with you to snap photos – on vacations, to sporting events, or wherever. QuickCam® Traveler™ is loaded with digital camera features like a self-timer, macro setting and storage for up to 200 pictures.” The camera has a list price of \$129.00 and comes with the USB cable and Microsoft NetMeeting video conferencing software as well as software for editing digital images.

2. Headsets

Another important peripheral is the headset. There are three kinds to choose from, the wired headset that plugs directly into the USB port, the radio frequency (RF) type and the infrared (IR) type.

Each type provides high quality speech with noise canceling technology. The wired type restricts mobility by being physically connected to the computer. The RF type has a range of 20 to 30 feet but cannot be used downrange with electrically initiated explosives. The IR sets can be used downrange when electrically initiated explosives are present, however the main drawback of the IR headset is having to keep the sender and receiver units pointed at each other to maintain the link, also there is a range limit of about 10 feet.

The high quality wired headsets cost between \$50.00 to \$60.00 dollars while the IR headset costs \$150.00. Figure 5.3 is an example of the RF wireless headset. This unit from Emkay is battery powered and sells for \$199.00.



Figure 5.4 Emkay RF wireless headset

The optimum solution is to have each type available so that the most appropriate choice can be made based on the conditions.

3. Personal Digital Assistants

The reasons for having a PDA down range are to provide backup computing capabilities and to take advantage of new attachments that are currently being developed for these devices.

If the downrange laptop suffers a catastrophic failure, a copy of the render safe procedure stored on the PDA could be used to complete the procedure. In urban settings, the PDA can use the cell phone module as a secondary form of communication. There are also attachments that turn PDAs into GPS receivers and digital cameras.

The recommended PDA is the Handspring Visor Prism.



Figure 5.5 Handspring Prism PDA

The Handspring PDAs use the Palm operating system, which currently supports the most accessories and software. The retail price is \$399.00, which includes the cell phone module.

4. GPS

GPS input to the laptop computer will allow navigation to the incident site using electronic maps. It will also show critical geographic information such as roads, airports and hospitals. It will also permit detailed mapping of debris fields in addition to ensuring the command post is outside the fragmentation radius or the downwind hazard area.



Figure 5.6 Earthmate GPS Receiver

The Earthmate GPS receiver by DeLorme plugs into the USB port and plots its position on the digital maps displayed on the screen. It comes with USGS topographic maps and street and trail maps loaded on DVD and has a retail price of \$249.00.

E. POWER SUPPLY HARDWARE

The purpose of the power supply is to provide a reliable power source that will keep the EOD wireless command and control system operating continuously for periods up to eight hours. In most instances, the command post will have access to a 110-volt power source from an electrical outlet or a portable generator that the EOD team already has. The downrange power supply will be provided by a combination of lightweight portable generator and high capacity long duration battery.

1. Generator Procurement Specifications

The requirements for the generator are:

- Must produce less than 60 dB of noise
- Must weigh less than 30 pounds

- Must operate over 4 hours on a single tank of fuel
- Must not exceed the physical dimensions 20 X 10 X 15

2. Light Weight Portable Generator Recommendation

The recommendation for the lightweight portable generator is the Honda EX700c.

This generator is small, lightweight, and quiet. It provides up to 700 watts of 60 Hz power for 4.5 hours on a single tank of fuel. The retail price is \$665.00


Specifications	Honda EX700C
Maximum AC Output (60Hz): 700 watts Rated AC Output (60Hz): 600 watts DC Output: 12V (6A) Continuous Operating Hours (approx.) 4.5 hr. Dimensions (LxWxH): 17.7" x 9.4" x 15.0" Dry Weight: 26.5 pounds Operating Noise 56 dB(A)	

Figure 5.7 Honda EX700c Generator

3. High Capacity Long Duration Battery

A recent breakthrough in laptop battery technology has allowed the creation of a battery that is advertised to power laptop computers for up to 16 hours. The PowerPad 160 from Electrofuel provides 15 volts, 11 Amp hours, and 160-watt hours of power on a full charge. The battery weighs 2.5 pounds and is .375 X 8.75 X 11.75 inches in size. The retail price is \$529.00



Figure 5.8 Electrofuel PowerPad 160

The combination of the Honda generator and the PowerPad 160 will ensure a reliable, lightweight, portable power source for the downrange electrical components.

The documentation for the VIP 110-24 spread spectrum RF transceiver lists the electrical power requirement as less than 5 watts, which the Honda generator will easily provide.

The Panasonic Toughbook 27 comes with a 3750-mAh battery. Although the documentation does not say how much operating time the battery will provide, there is some information provided that can be used to calculate the computers power requirements.

The computers information sheet states that the battery recharge time is 2.5 hours with the computer off and 5.5 hours with the computer on. Since the battery stores 3750 mA and it takes 2.5 hours to charge, the battery charger can charge at a rate of 1500 mAh ($3750 \text{ mA} / 2.5 \text{ hours} = 1500 \text{ mAh}$). Because it takes the charger 5.5 hours to charge the battery with the computer on, the charger will provide 8250 mA during this period (5.5

hours X 1500 mAh = 8250 mA). Subtracting the amps the battery stored from the amps provided by the charger leaves the remainder that was consumed by the computer over a period of 5.5 hours, which is 4500 mA ($8250 \text{ mA} - 3750 \text{ mA} = 4500 \text{ mA}$). When this is divided by the 5.5 hours, the computer used 818 mA in one hour ($4500 \text{ mA} / 5.5 \text{ h} = 818 \text{ mA}$). Dividing the battery capacity of 3750 mAh by the 818 mA will yield an operating time of 4.5 hours.

The PowerPad 160 will provide an additional 11000 mA for a total of 14750 mA ($11000 \text{ mA} + 3750 = 14750$). To account for additional power drain caused by the digital video camera and the GPS receiver through the USB port, a conservative factor of 2 will be applied, doubling the power consumed by the computer ($2 \times 818 \text{ mA} = 1636 \text{ mA}$). Dividing the total mA available by the mA consumed by the computer produces an operating time of 9.01 hours, ($14750 \text{ mA} / 1636 \text{ mA} = 9.01$) which satisfies the 8-hour duration requirement.

F. PROTECTIVE STORAGE CASE

All the hardware components must be protected during storage and transportation.

The best product to accomplish this is the Pelican storage case. These boxes are made of a high impact copolymer resin with a protective foam liner. They are waterproof, dustproof, and crush proof. These boxes have an atmospheric vent for pressurization changes during flight and also come in different sizes and colors. Figure 5.9 shows the Pelican laptop storage container model 490.



Figure 5.9 Pelican Storage Case Model 1490

All the hardware components can fit in four Pelican cases, two model 1490 cases for the laptops, video cameras, and GPS receivers, and two model 1700 cases for the VIP 110-24 transceivers and antennas. This satisfies the portability requirements for size, weight, and number of containers. Figure 5.10 shows the model 1700 case.

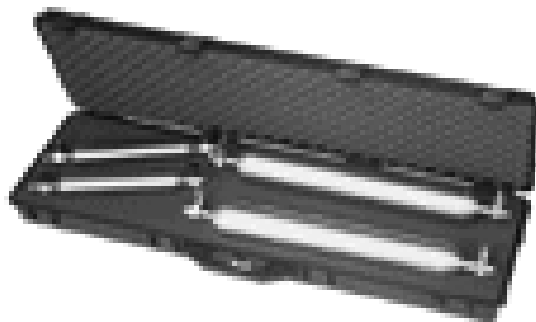


Figure 5.10 Pelican Storage Case Model 1700

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VI. SOFTWARE ANALYSIS

A. INTRODUCTION

The software analysis will include the selection of the operating system and the applications. The goal is to provide the highest degree of compatibility and functionality to the user. One application mandated for use is the Automated Explosive Ordnance Disposal Publication Set (AEODPS). This is the electronic technical library database that contains the entire EOD 60 series publication set on compact disc. It is a Windows based information system used by EOD technicians for ordnance identification, and to develop render safe procedures in the field.

B. OPERATING SYSTEM

The operating software chosen for the EOD wireless command and control system is Windows 2000. The selection of this operating system is based on hardware and software compatibility issues, enhanced network and security features provided by Windows 2000, and because it is the most current version of an operating system that most people are familiar with. Windows 2000 Professional comes preloaded on the laptops from the manufacturer so there are no additional costs for this operating system.

The hardware compatibility considerations occur with the utility and configuration software for the UC VIP 110-24 radio transceiver, which requires a Windows environment, also, both the Logitech Traveler Quickcam and the Earthmate GPS receiver can only be used within Windows.

A Windows environment is required to use the automated EOD publication set (AEODPS). This is a core application that has no substitute and must be used. The other applications selected are also Windows based.

The Microsoft Windows 2000 textbook describes Windows 2000 Professional as:

“Windows 2000 Professional is the main Microsoft desktop operating system for businesses of all sizes. It is a high-performance, secure-network client computer and corporate desktop operating system that incorporates the best business features of Windows 98 and builds in the traditional strengths of Windows NT Workstation. Windows 2000 Professional includes a simplified user interface, plug and play capabilities, enhanced power management, and support for a broad range of hardware devices. In addition, Windows 2000 Professional significantly extends the manageability, reliability, and security of Windows NT because of its new file encryption system and application management tools.”

The minimum hardware requirements for Windows 2000 professional are listed in table 6.1

Component	Minimum Requirement
Processor	32-bit Pentium 133 MHz
Free Hard Disk Space	671 MB minimum, 2 GB recommended
Memory	64 MB for networking one to five client computers
Display	VGA monitor capable of 640 X 480 1024 X 768 recommended
CD-ROM drive	12x or faster
Additional drives	High-density 3.5-inch drive
Optional components	Mouse or other pointing device

Table 6.1 Minimum Hardware Requirements for Windows 2000

C. APPLICATIONS

The applications that are chosen for the EOD wireless command and control system will provide the software tools that are needed to conduct EOD incident responses. The laptop computers will have Microsoft Office 2000 or the latest version

preloaded from the manufacturer. The remaining applications are either proprietary software that provides functionality to hardware and peripherals such as the radio transceiver, video camera, and GPS receiver or they are military specific applications like the AEODPS system and the Defense Message System (DMS). EOD specific decision support software will be developed and added in the future. All the application software is included with the associated hardware so there are no additional application costs.

1. Automated Explosive Ordnance Disposal Publication System

The AEODPS is the electronic EOD 60-series publication set. It is a Windows based interactive technical database that allows EOD technicians to search by physical attributes and nomenclature to identify ordnance and to create render safe procedures based on the publications guidance. The software is currently contained on a multi disc CD-ROM set. This application will reside on both the command post and downrange laptop.

2. Microsoft NetMeeting

Microsoft NetMeeting is chosen as the video conferencing application. It is included in the Office 2000 bundle and also with the Logitech video camera software.

This application allows voice, video, and data sessions to occur simultaneously. NetMeeting dynamically controls the bandwidth giving the highest priority to maintaining the voice connection. The second priority is to maintain the data connection, and the remaining bandwidth is allocated for the video connection. There is a whiteboard feature that permits participants to work on a common board. NetMeeting also supports application sharing.

Some of its features include the ability to control the size and quality of the video display and password protection for sessions as well as encryption for data transmission.

Results obtained by Microsoft while testing various user scenarios for NetMeeting provides good data on bandwidth application requirements. The results show that maintaining a high quality video connection while sharing applications used 600 Kbps of bandwidth on average with peaks of 700 to 900 Kbps. Based on the results of the link margin analysis, there is a enough bandwidth to support NetMeeting sessions to a range of 13 Miles.

3. Peripheral Applications

The GPS and the web video camera each come with proprietary software bundles that provide functionality with the hardware. The GPS can be used with its map software to navigate with a moving map display. The web video camera has software that allows digital pictures to be downloaded from the camera and edited.

The Handspring PDA uses software to hot sync with applications stored on the laptop. This will allow critical documents like the render safe procedures to be loaded into the PDA as a backup in case the downrange laptop fails during a procedure.

4. EOD Decision Support System

A future add on software package is the EOD decision support system. This software package would be written in a language like Visual Basic and provide support through a graphical user interface (GUI) while conducting specific EOD missions. Some of the envisioned capabilities would be to automatically calculate blast and fragmentation radii based on the item's identification with AEODPS, and then plot it on the electronic

map. It could also map contamination patterns and plot the downwind hazard areas from input received by remote robotic sensors and current metrological conditions available through the Internet. Each EOD mission area would have a module to automate planning and administrative functions as well as perform calculations and plotting currently done manually.

D. SOFTWARE SUMMARY

The software described here represents a sampling of what is currently available. Because software development is such a dynamic area, there will undoubtedly be newer and better applications available before the EOD wireless command and control system is implemented. The XP operating system from Microsoft is weeks away from release. This new software will provide the same functionality described above but will do it faster, more reliably and with greater security. The critical factor is to use applications and operating systems that are designed to be compatible so that the most robust configuration is achieved.

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VII. SYSTEM CONFIGURATION

A. INTRODUCTION

The previous chapter identified the components that make up the EOD wireless command and control system. This chapter will explain the arrangement of the components, how they will be used, and discuss the limitations and vulnerabilities of the system.

B. SYSTEM ARRANGEMENT

The EOD wireless command and control system consists of the command post components group and the downrange components group.

1. Command Post Components

The command post has a Panasonic Toughbook 27 laptop computer connected to a UC Wireless VIP 110-24 spread spectrum transceiver by up to 295 ft of category 5 LAN cable. The transceiver uses the OA2.4-9 Omni-Directional antenna. The command post laptop has the Logitech Traveler Quickcam and the Earthmate GPS receiver connected by USB cable.

The command post also has a spare VIP 110-24 transceiver that can be used to support a second incident site. It can also act as a relay station when line of site cannot be established between the command post and the downrange site, or an emergency spare if one of the other transceivers become damaged or fails.

A wall outlet or a generator when operating in remote locations supplies the power to the command post components.

The laptop computer, the camera, and the GPS are stored in one Pelican case, while the VIP 110-24 transceivers and the antenna are stored in the other.

2. Down Range Components

The down range components consist of a Panasonic ToughBook 27 laptop computer connected to a VIP 110-24 transceiver. The transceiver is connected to a Yagi or semi-parabolic antenna by up to 295 ft of category 5 LAN cable which is the maximum span of cable supported by the Ethernet standard. The Logitech Traveler Quickcam and the Earthmate GPS receiver are attached to the laptop by USB connections. The Handspring Prism PDA is not connected to the laptop but has a copy of the RSP loaded into its memory as a backup and is carried by the EOD technician.

The Honda EX700c generator supplies power to the transceiver, while the laptop's internal battery and the Electofuel Power Pad 160 supply power to the laptop and peripherals.

The laptop and peripherals fit in one Pelican case, the transceiver and antenna fit in the other.

C. MODES OF OPERATION

The ability to adapt the EOD wireless command and control system to different conditions is essential to maintain the vital communication link between the command post and the downrange site. The modes of operation describe how the system will maintain the link in different environments. Each of the following scenarios describes ways the system can be adapted to the environment. The critical factor in all cases is to maintain a line of sight between the antennas at the command post and the incident site.

1. Conventional Land Response

The conventional land response is the simplest scenario. The terrain can be anything from urban, to jungle, to desert. It requires a command post be established outside the blast and fragmentation radius of the explosive item.

If a LAN is available such as on a school or corporate campus, the laptops can use the existing network to connect. The only physical limitation is the 295 ft length of LAN cable to connect to the network.

When a network is not available, the command post omni-directional antenna needs to be placed as high as possible. This can be accomplished by using available buildings or trees. Another option is to use an advertising blimp to raise the antenna. A 1998 conceptual study by the Naval Facilities Engineering Service Center at Port Hueneme California describes using tethered Aerostats to establish a communication link. [5] The same concept can be applied to the EOD wireless command and control system. The advertising blimps can be ordered in various sizes for fewer than five hundred dollars. This arrangement would permit the antenna to be raised to an altitude of up to 295 ft, thus providing clear line of sight.

2. Nuclear, Biological, Chemical Response

The Nuclear, Biological, and Chemical (NBC) response is more complicated than the conventional land response. It requires that a command post be established up wind from the incident site, this reduces the options for locating the command post. The line of sight challenge can be overcome using the same options given in the conventional scenario.

The other complication is the protective clothing that must be worn by the downrange team, which prohibits clear voice communication. The best option is to use an RF wireless headset modified to wear under the protective clothing. This will permit the downrange team leader to have clear communication with the command post.

The last consideration with an NBC environment is how to decontaminate the downrange components. The high value items like the laptop and the transceiver are environmentally sealed and can be decontaminated along with the other equipment. The Logitech Quickcam can be sealed in a disposable underwater camera case and the Earthmate GPS can be sealed in zip lock plastic bags. Using these methods should allow recovery of all the downrange components.

3. Shipboard Incident Response

Setting up the EOD wireless command and control network in a shipboard environment can be done a couple of different ways. If the ship is modern enough to have its own network, the laptops can be connected through the ship's LAN. In other circumstances, the antennas can be placed outside the skin of the ship or within line of sight such as across a hanger bay. Taking advantage of the 295 ft LAN cable at each antenna will provide a total of 590 ft of wire, which should provide adequate separation for most ships. The third transceiver could be used as a relay between the command post and the incident site if required.

4. Small Boat Operations

The last scenario describes diving and mine countermeasures operations conducted by EOD from small boats. Although there is no command post established by the EOD team during these evolutions, the EOD team is attached to a command element operating from shore or a larger support ship. Under these circumstances, it is still essential to maintain a communication link with the command element for situation reports and medical evacuation.

This can be accomplished the EOD wireless command and control network by making a few changes to the configuration. The small boat uses the advertising blimp to fly the omni-directional antenna at 295 ft while the command ship or shore facility keeps a semi-parabolic antenna pointed at the blimp. Looking at the link margin chart for the semi-parabolic antenna shows a theoretical range of greater than 15 miles with a bandwidth of 5.5 Mbps.

D. SYSTEM LIMITATIONS

The limitations of the EOD wireless command and control network are caused by the limits of the hardware and software components that make up the system and by the environments they will be used in. The most significant limitations are listed below:

- Power must be supplied to the transceivers to maintain the link.
- The downrange generator needs refueled every 4.5 hours.
- The battery power for the downrange laptop will last about 9 hours before needing recharged.
- All the antenna combinations require line of sight to maintain the link.
- The Yagi antenna has a range limit of 9 miles in order to provide a 2 Mbps data rate.
- Applications must run in a Windows environment.
- HERO limits must be observed in the vicinity of electrically initiated ordnance.

The HERO restrictions present a significant challenge that can be overcome by using the LAN cable to keep the downrange antenna a safe distance from electrically initiated ordnance. The directional Yagi antenna focuses the signal in a narrow pattern in the direction it is pointed, with only a very small portion of the transmitted power radiating off axis.

The calculations to determine the power density behind a directional antenna are complex and beyond the scope of this work. To provide some understanding of the separation distances required, a worst case of spherical spreading will be assumed, where the transmitted power is radiated equally in all directions.

The equation for spherical spreading is given as:

$$I = \frac{P_s}{4 \pi r^2}$$

Where:

I = the power density in mW/cm²

P_s = the power at the antenna in mW

r = the distance from the antenna in cm

In order to solve for r , the 38 dB ERP of the Yagi antenna must be converted to watts, resulting in P_s being equal to 6.310×10^6 mW. The graph in Figure 7.1 provides values for I . Using the most sensitive case of HERO limit 2 (which is the worst case, for unsafe or unreliable ordnance) and a frequency of 2.4 GHz results in I being equal to 0.1 mW/cm². Solving the spherical equation using these values yields a result of 73 ft of separation.

A more realistic approximation would be to consider that 20 percent of the antenna's power is radiated off axis. Solving the spherical equation with this approximation gives a value of 33 ft of separation. This is well within the 295 ft limit of the category 5 LAN cable.

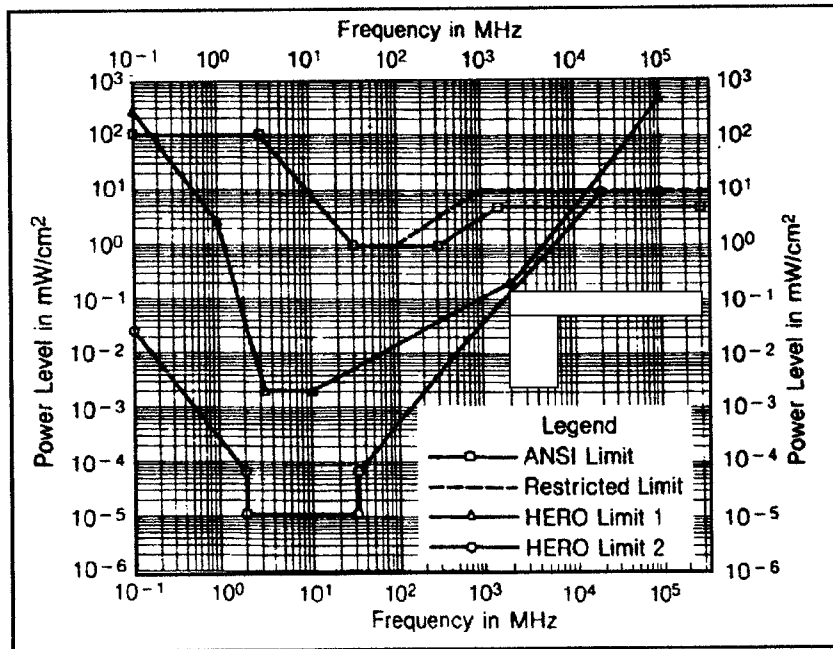


Figure 7.1 HERO Limits from OP3565

F. SYSTEM VULNERABILITIES

The vulnerabilities of the EOD wireless command and control system are similar to those of any computer network. The greatest vulnerability is the system hardware because of the environment it will be used in. The physical conditions may exceed the environmental limits of the components.

Although the components have been specifically selected to provide the most robust configuration, the system is still vulnerable to power loss, power fluctuations, and component failures. Due to the extreme conditions that may be encountered, component failure may occur at a greater rate than with normal systems. The network operators will ultimately play a significant role in determining the reliability of the components based on the level of care that is given when using the system.

Certain design features of the EOD wireless command and control network make it far less vulnerable to compromise and exploitation than other systems. The following reasons explain why network security is not considered to be vulnerable.

The hardware provides link security by using spread spectrum RF, which limits the effects of interference and jamming.

The use of hardware that avoids the 802.11b standard reduces the vulnerability to hacking. The security weakness of this protocol was revealed in the 2001 Naval Postgraduate School thesis by Mel Yokoyama titled “AIRBORNE EXPLOITATION OF AN IEEE 802.11B WIRELESS LOCAL NETWORK”. [6] In this work Lt Yokoyama showed that 802.11B systems could be penetrated and exploited using system utility programs.

To gain access to the EOD wireless network would require that a person have identical hardware, with the correct access code, and the correct password. The attacker would also have to be within the link margin distances listed in table 5.4 and 5.5. Only then, could someone intercept network traffic.

Additionally, the Windows operating system has an advanced security architecture that provides session level security. There are several schemes to ensure the authentication, integrity, and confidentiality of each session. These include public key infrastructure (PKI), which uses certificates for encryption and authentication, and the Kerberos protocol for authenticating users during login. Network traffic that is somehow intercepted, is also encrypted thus maintaining integrity and confidentiality.

The chance of virus infection and remote attack is minimal because the network is a private isolated network. Accessing the EOD wireless command and control system would only provide EOD specific information. This makes it a low value target that is very difficult to attack because it moves to different locations and operates for only brief periods of time. For these reasons, network security is not considered a vulnerability.

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VIII. SYSTEM COSTS

A. INTRODUCTION

The lifecycle costs of information systems are normally divided into thirds, one-third for procurement, one-third for operations, and one-third for maintenance. The lifecycle costs for the EOD wireless command and control system is expected to be somewhat different with a greater portion going for initial procurement.

The operating costs are minimal because there is no additional labor costs and the only consumables are batteries for the laptop and peripherals, and fuel for the generator. The information technology division at each EOD mobile unit will configure the system and provide user training, and each detachment will operate the network with existing personnel.

The maintenance costs are limited to replacing damaged and broken components and lifecycle replacement of obsolete hardware and software. It is assumed that the computer hardware and software will need to be replaced every three to five years to keep the system current.

A more realistic breakdown of the cost is 30 % for initial procurement, 60 % for maintenance, and 10 % for operations.

B. PROCUREMENT COSTS

The procurement costs are the sum of all hardware and software needed to build the system. Table 8.1 summarizes the hardware procurements costs. These costs were obtained directly from the vendors web sites or by phone quotations.

ITEM	QUANTITY	COST	TOTAL
Panasonic Laptop Computer	2	\$ 4,999	\$ 9998
UC Wireless Transceiver	3	\$ 1,598	\$ 4794
Omni Directional Antenna	1	\$ 298	\$ 298
Yagi Antenna	1	\$ 325	\$ 325
Semi Parabolic Antenna	1	\$ 365	\$365
Handspring Prism PDA	1	\$ 399	\$ 399
Earthmate GPS	2	\$ 249	\$ 498
Logitech Video Camera	2	\$ 129	\$ 258
Honda Generator	1	\$ 665	\$ 665
Electrofuel PowerPad 160	1	\$ 529	\$ 529
Pelican Case Model 1490	2	\$ 236	\$ 472
Pelican Case Model 1700	2	\$ 239	\$ 478
IR Headset	1	\$ 150	\$ 150
RF Headset	2	\$ 199	\$ 398
Wired Headset	2	\$ 60	\$ 120
		TOTAL	\$ 19,747

Table 8.1 Hardware Procurement Costs

The software costs are built into the procurements costs. The Windows operating system and Microsoft Office 2000 are preloaded on the laptops from the manufacturer. The remaining software is proprietary and is provided with the transceivers and peripherals.

The entire system can be purchased for less than \$ 20,000 dollars. Rounding up to \$ 25,000 will permit significant redundancy by purchasing additional spare components such as another Honda generator, an additional PowerPad, and extra antennas and transceivers.

C. TOTAL SYSTEM COSTS

Based on the initial procurement costs of \$ 25,000 dollars and using the lifecycle distribution of 30 % for procurement, 60 % for maintenance and 10 % for operations with a three to five year replacement cycle. The total system cost for 15 years is forecast to be \$ 100,000. This equates to \$ 6,666 per year, which offers considerable value for the capability the system will provide.

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IX. SUMMARY

A. CONCLUSIONS

Based on the results of this work, it is feasible to construct a wireless command and control system for EOD with commercial off-the-shelf components that meets or exceeds the design requirements defined in chapter III. The capacity of the system will also accommodate new capabilities as advances are made in using robotics and remote sensing and monitoring for EOD operations. Table 9.1 compares the design requirements with the capabilities.

Requirement	Capability
Downrange components less than 50 lbs, command post components less than 100 lbs	Both downrange and command post components weigh less than 50 lbs including storage cases
8 hour endurance	Over 9 hour endurance
5 mile range	Up to 15 miles
1.5 Mbps bandwidth capacity	Up to 11 Mbps
\$ 45,000 to \$ 50,000 initial procurement	\$ 20,000 initial procurement

Table 9.1 Design Requirements vs. System Capabilities

These are capabilities that can be determined based on specification analysis and calculations. There are many other capabilities that can only be determined by building and testing the network. Reliability and delay metrics are best evaluated on the actual system.

The low cost of the components provides an outstanding value for the improvements over existing capabilities. The advantages offered by the system will allow new tactics to be implemented that provide quantum leaps in efficiency and safety.

This system can also fill the needs of other organizations that have a requirement to establish remote command posts away from incident sites.

B. RECOMMENDATIONS

The first recommendation is for the EOD Technology Division to build a prototype of the EOD wireless command and control system for testing and evaluation. It is further recommended that if testing and evaluation yields positive results, the system be approved and funded for use by EOD teams in the field.

Other recommendations are focused on changing current EOD tactics to leverage the capabilities of the new system. The present standard operating procedure (SOP) for EOD teams is to conduct one RSP operation at a time. This is based on the limits of the current command and control system. It is not possible to have connectivity simultaneously with two geographically separated sites using the hardwire intercom. Normally only one or two people are working downrange while five or six remain at the command post.

A new tactic of using two downrange teams simultaneously will permit much more efficient operations by fully utilizing everyone on the team. This is possible because the wireless link can provide connectivity with two geographically separated locations.

The normal EOD team consists of one officer and seven enlisted members. The Officer-in-Charge (OIC) can man the command post with two enlisted while the downrange teams operate at separate sites. Obviously, simulations operations are more complex and place a greater workload on the command post. There are also problems with tools and equipment as well as transportation from the command post to the sites. These difficulties can be overcome by changing the allowance to permit duplicates of

certain tool sets and equipment, and by using all-terrain vehicles like Quadrunners with small utility trailers for transportation

Clearly this idea will not work in all scenarios, but in most cases it will permit one EOD team to cover a much larger geographic area at a much greater rate, thus providing a quantum leap in efficiency.

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VIP 110-24

Operator's Manual

Rev: A

August, 2001

UC Wireless Inc.
323 Love Place
Santa Barbara, CA 93117

Tel: (805) 964 5848

FCC Notice

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved in writing by UC Wireless Inc. may void the user's authority to operate this equipment. UC Wireless can not accept any financial or other responsibilities that may be the result of your use of this information, including direct, indirect, special, or consequential damages. Refer to warranty documents for product warranty coverage and specifics.

STATEMENT OF WARRANTY

UC WIRELESS products, except as otherwise stated in an applicable price list, are warranted against defects in workmanship and material for a period of one (1) year from date of delivery as evidenced by UC WIRELESS's packing slip or other transportation receipt.

UC WIRELESS's sole responsibility under this warranty shall be to either repair or replace, at its option, any component which fails during the applicable warranty period because of a defect in workmanship and material, provided PURCHASER has promptly reported same to UC WIRELESS in writing. All replaced Products or parts shall become UC WIRELESS's property.

UC WIRELESS shall honor the warranty at UC WIRELESS's facility in Goleta, California. It is PURCHASER's responsibility to return, at its expense, the allegedly defective Product to UC WIRELESS. PURCHASER must notify UC WIRELESS and obtain shipping instructions prior to returning any Product. Transportation charges for the return of the Product to PURCHASER shall be paid by UC WIRELESS within the United States. For all other locations, the warranty excludes all costs of shipping, customs clearance and other related charges. If UC WIRELESS determines that the Product is not defective within the terms of the warranty, PURCHASER shall pay UC WIRELESS all costs of handling, transportation and repairs at the prevailing repair rates.

All the above warranties are contingent upon proper use of the Product. These warranties will not apply (i) if adjustment, repair, or parts replacement is required because of accident, unusual physical, electrical or electromagnetic stress, negligence of PURCHASER, misuse, failure of electric power environmental controls, transportation, not maintained in accordance with UC WIRELESS specifications, or abuses other than ordinary use (ii) if the Product has been modified by PURCHASER or has been repaired or altered outside UC WIRELESS's factory, unless UC WIRELESS specifically authorizes such repairs or alterations; (iii) where UC WIRELESS serial numbers, warranty date or quality assurance decals have been removed or altered.

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INTRODUCTION

The *VIP 110-24* is the building block of the UC Wireless proprietary “VINE” Network topology. This unique network topology can be used to provide broadband internet access by a Service Provider or to interconnect multiple nodes in a private network.

The VINE technology allows a complete wireless network to start with as little as two radios, and gradually grow, a node at a time, into a very large and complex wireless network. New nodes can be added at any time with the sole requirement that they must have line of sight connectivity to another node already on the VINE. The new node, once attached, becomes a potential attaching point for other nodes.

VINE uses time, frequency, and directional diversity to coordinate the Medium Access for all the nodes. This well choreographed diversity allows multiple nodes to transmit without collisions in the same geographical area. This results in a very high air time utilization which translates into superior throughput performance.

VINE is designed to specifically address the following requirements:

- Gradual deployment and expansion
- Long distance between nodes
- Support of multi-hop transmissions. Not all nodes need to be in line of sight
- Highly efficient air time utilization
- Efficient delivery of broadcast traffic (necessary for network management)
- Fair network availability under heavy loads (a few nodes with heavy load must not “choke” the network availability to all other nodes)
- Node by node Quality Of Service Options: Minimum and maximum user data rate settings separate for inbound and outbound traffic
- Automatic RF data rate selection on each individual link.
- Self configuring allowing new nodes to be added with minimal configuration

The *VIP 110-24* is a Spread Spectrum transceiver that implements the VINE protocol. The radio includes a 10/100-Base T Ethernet port for connection to the Local Area Network (LAN). The radios can be set to operate in either Bridge mode or Router mode. In bridge mode, any station connected to the LAN can see any other station connected to all the other LANs at the remote sites. No special configuration of the user stations is necessary, as each of them believes that there is just one Ethernet.

The *VIP 110-24* is a Spread Spectrum radio operating in the “Industrial Scientific and Medical” (ISM) band from 2.400GHz to 2.4835 GHz. Spread Spectrum technology allows operation without a license with an output power of up to 23 dBm at speeds up to 11 Mbps (mega-bits per second).

With exception of the indoor power inserter, all of the *VIP 110-24* electronics are included in a watertight outdoor unit enclosure. A single CAT 5 cable carries the Ethernet data and DC power to the outdoor enclosure. This architecture allows the radio to be mounted outdoors, in close proximity to the antennas, resulting in the following benefits:

- The radio Low Noise Amplifier (LNA) is as close to the antenna as possible. The cable run between the antenna and the outdoor unit is usually short and therefore cable losses at 2.4 GHz are negligible. This improves the overall link margin.
- The unit Power Amplifier is also in close proximity to the antenna. All the power is delivered to the antenna with minimal losses in the cable.

The *VIP 110-24* also includes a number of unique features that make the unit easy to install and operate:

- Spectrum analysis capability with a graphical display of the energy in the RF band
- Accurate measurement of the Receive Signal Strength (RSS)
- Antenna Alignment Aid output, at the outdoor unit, with an audio pitch proportional to the RSS
- Automatic adjustment of RF speed to adapt to the RF link margins
- Automatic adjustment of the RF transmit power to manage frequency reuse
- Multitude of frequency channels allow operation anywhere in the band
- Dual antenna port to support store and forward operation in the unique VINE network topology
- Remote configuration of all radios in a network from a single station
- Capability of downloading firmware updates over Ethernet and RF links

Refer to section 5.1 for a “Quick Start” guide to set up the radios.

SPECIFICATIONS

RF Specifications						
RF Frequency Band		2.410 GHz to 2.470 GHz (center freuecies)				
RF Signal Bandwidth (-20 dBc)		18 MHz				
RF Channels		31 (4 non-overlapping)				
Transmitter Output Power		0 to 23 dBm (programmable)				
Modulation Type		direct sequence spread spectrum				
RF Data Rates (one way)		1, 2, 5.5, 11 Mbps				
Receiver Sensitivity (10 ⁻⁶ BER)		-89	dBm	(@	1	Mpbs)
		-86	dBm	(@	2	Mbps)
		-84	dBm	(@	5.5	Mbps)
		-81	dBm	(@	11	Mbps)
Data Interfaces						
Auxiliary Port		RS-232				
Ethernet Port		10/100 BaseT				
Power Requirements						
Input Voltage (Outdoor Unit)		+12 to +24 Volts DC				
Input Voltage (AC)		110 VAC or 220 VAC				
Power Consumption		less than 5 Watts				
Environment						
Temperature		-35 to +65 Degrees C				
Max. Humidity		90% non-condensing				
Mechanical:						
Dimensions		3.14” wide x 2.24” high x 4.92” deep (79mm W x 56 H x 125 D)				
Weight		2.4 lbs. (1.1 Kg).				

PRODUCT DESCRIPTION

RADIO COMPONENTS

Figure 3.1 shows the components that are typically shipped with each *VIP 110-24* radio.

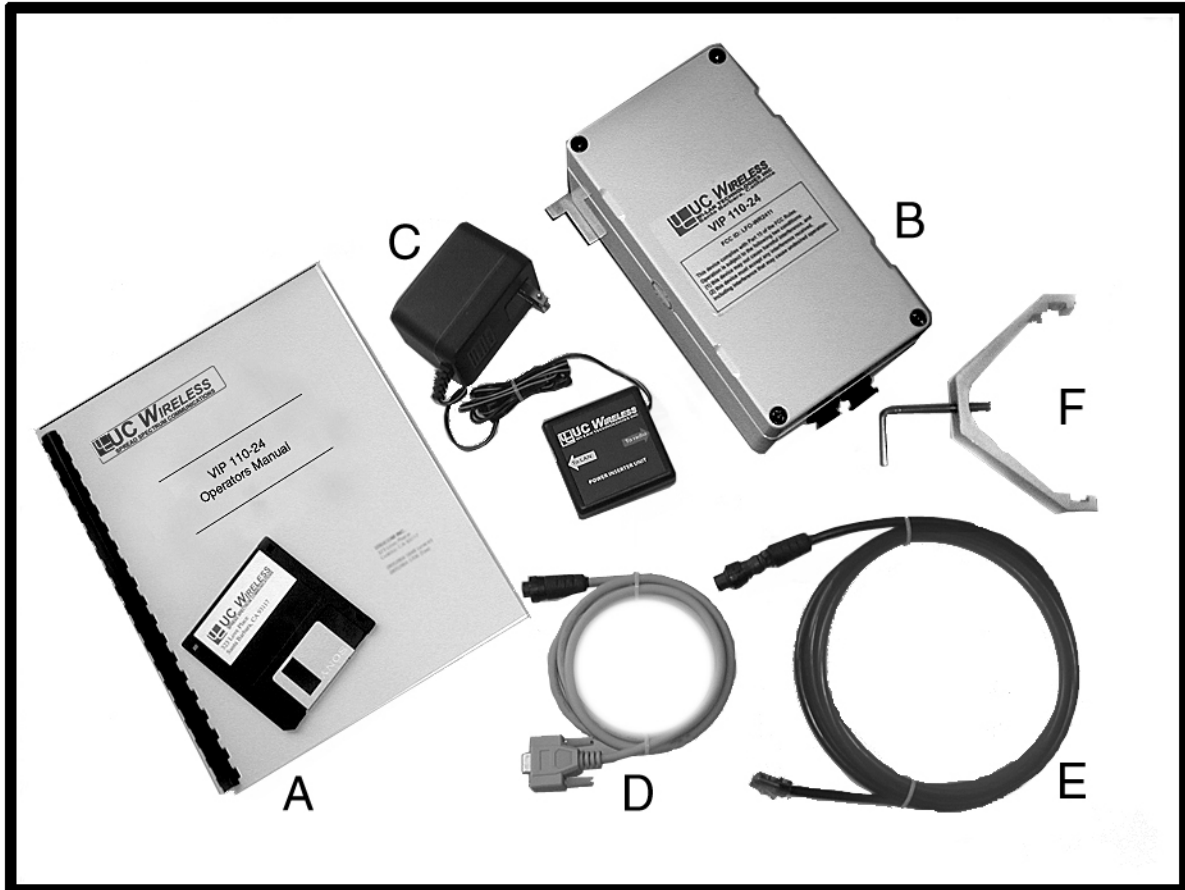


Table 3.1 - VIP 110-24 Components

A	This manual and floppy disk with Econsole program
B	<i>VIP 110-24</i> outdoor unit.
C	Power Inserter Module with wall mount AC power supply
D	Auxiliary port cable for RS-232 connection (optional)
E	CAT 5 cable for connection between <i>VIP 110-24</i> radio and power inserter module
F	Bracket for securing the <i>VIP110-24</i> unit to an outdoor mast.

RADIO CONNECTORS

Figure 3.1 shows the *VIP 110-24* radio mounted on a mast. The radio is housed in a rectangular enclosure with two N-female connectors at the top for connection to RF antennas, and two special purpose connectors at the bottom for DC power, Ethernet data and control.



The function of each connector is described in the table below.

Table 3.1 – VIP 110-24 Connectors

CONNECTOR	TYPE	Function
R		
A	N-FEMALE	2.4 GHz RF connector to the upstream (directional) antenna
B	N-FEMALE	2.4 GHz RF connector to the downstream (omni or sector) antenna
C	Switchcraft	Auxiliary port (3 pin) used as an antenna alignment aid and for RS-232 console port.
D	Switchcraft	10/100 Base-T data interface and DC power input (8 pin). Must be connected to the “Power Inserter Unit” with a CAT 5 cable.

An eight conductor CAT 5 cable must be connected between the *VIP 110-24* and the Power Inserter Unit. The wiring for this cable is shown in figure 3.2.

The table 3.2 shows the pin assignment of the three pin, auxiliary port cable. The unit is shipped with a plug in this connector. The connector can be used during installation as a console port and also as a audio antenna alignment aid

Table 3.2 - Auxiliary Port Connector Pin Assignments

Pin	Signal Name	Abbr.	Direction
1	Receive Data	RD	Radio Output
2	Transmit Data	TD	Radio Input
3	Ground	GND	

POWER INSERTER UNIT

The Power Inserter Unit includes a wall mount power supply wired to a small plastic enclosure with two RJ45 connectors and a bi-color LED. The two RJ-45 connectors are labeled “To LAN” and “To radio”. The following tables describe those connectors.

Table 3.3 – Power Inserter Unit

Connector/LED	Type	Function
To LAN	RJ-45	10/100 Base-T to be connected to the Local Area Network. Use a straight through cable to connect to a hub and a cross over cable to connect directly to a computer. See table 3.4 for pin assignments.
To radio	RJ-45	Carries the DC power and Ethernet signals to the <i>VIP 110-24</i> . See table 3.5 for pin assignments.
LED	Amber/ Green	<p>Amber: Indicates that the power inserter unit has DC power from the wall supply but no power is being drawn by the <i>VIP 110-24</i>.</p> <p>Green: Indicates that the <i>VIP 110-24</i> is drawing power.</p>

WARNING

The Power Inserter connector labeled “To radio” includes DC voltage in two of the pins. It must not be connected to a LAN as this voltage may damage some LAN cards.

Table 3.4 – “To LAN” Ethernet Connector Pin Assignments

Pin	Signal Name	Abbr.	Direction
1	Ethernet Tx	Tx (+)	Radio to Ethernet
2	Ethernet Tx	Tx (-)	Radio to Ethernet
3	Ethernet Rx	Rx (+)	Ethernet to Radio
4	(not connected)		
5	(not connected)		
6	Ethernet Rx	Rx (-)	Ethernet to radio
7	(not connected)		
8	(not connected)		

Table 3.5 – “To radio” Ethernet Connector Pin Assignments

Pin	Signal Name	Abbr.	Direction
1	Ethernet Tx	Tx (+)	Radio to Ethernet
2	Ethernet Tx	Tx (-)	Radio to Ethernet
3	Ethernet Rx	Rx (+)	Ethernet to Radio
4	+18 VDC	DCV (+)	Power Inserter to Radio
5	+18 VDC	DCV(+)	Power Inserter to Radio
6	Ethernet Rx	Rx (-)	Ethernet to Radio
7	18 VDC ground	GND(-)	Power Inserter to Radio
8	18 VDC ground	GND(-)	Power Inserter to Radio

OUTDOOR INTERCONNECT CABLE

The interconnect cable between the Power Inserter Unit and the *VIP 110-24* carries the following signals

1. DC voltage to supply power to the *VIP 110-24*.
2. 10 Base-T Ethernet data.

Both these signals are carried in a single CAT 5 cable. The system is designed to allow cable lengths up to 70 meters. Figure 3.2 shows interconnect diagram for this cable and connector types. Table 3.6 lists a few part numbers and sources of appropriate CAT 5 cable for this application. UC Wireless carries several pre-made cables of different lengths.

RJ 45

EN3

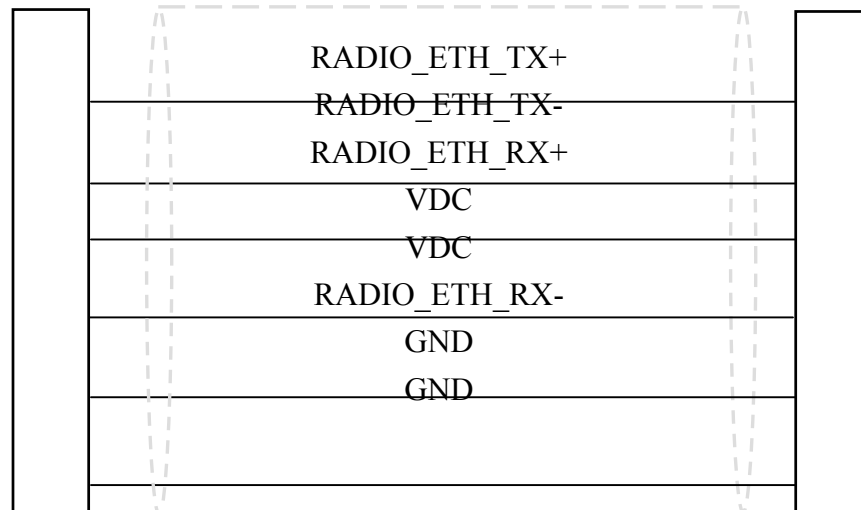




Fig 3.2. CAT 5 Outdoor Interconnect cable diagram

Table 3.6 – Indoor/Outdoor Unit CAT 5 cable

Part number	Manufacturer	Description
04-0010-34	Superior Essex	Industrial shielded, weatherproof cable for direct burial, aerial and other severe environments
18-241-31(gray) 18-241-11 (beige)	Superior Essex	Unshielded outdoor rated cable
5EXH04P24-BK-R-CMS-PV	CommScope	Unshielded outdoor rated cable
2137113 (ivory) 2137114 (gray)	General Cable	Unshielded outdoor rated cable
BC1002	Belden	Unshielded outdoor rated cable

ANTENNAS, SITE SELECTION, PATH ANALYSIS

INTRODUCTION

NOTE

Basic instructions for connecting the antenna to the radio are given in section 5. If the system is to be used at short to moderate ranges and there are no major obstructions between antennas, the more detailed information in this section may not be necessary.

Because *VIP 110-24* radios communicate with each other by means of radio waves, all aspects of antenna installation affect their performance significantly, namely:

- antenna type used
- clear line-of-sight path between antennas
- antenna orientation
- antenna placement
- antenna-to-antenna distance between radios
- distance between the radio and its antenna (antenna cable length)

Therefore antenna installation is a vital part of system installation. Improper installation may greatly reduce system performance, possibly rendering the system inoperable.

This section discusses these issues and provides guidelines for selecting antenna type, selecting antenna location, and achieving an optimally functioning installation.

SELECTING ANTENNA TYPE

There are a vast number of antenna types designed for various general and special purposes, but despite the huge variety, all designs essentially address two concerns, directionality and gain. These selection criteria are discussed in the following paragraphs, along with a third criterion, polarization.

For the *VIP 110-24*, the three antenna types listed below will fulfill most installation requirements.

Antenna Type	Gain	UCW Model Number
Omnidirectional	9 dBi	OA2.4-9
Sector	12 dBi	2405H-90
Semi-Parabolic	24 dBi	DA2.4-24

Directionality

An antenna may be designed to receive and transmit in all directions. Such antennas are omnidirectional. An example of an omnidirectional receiving antenna would be a television antenna in a metropolitan area where each television station transmits its signal from a different location relative to the receiver. Similarly, a centrally located television transmitter would use an omnidirectional transmitting antenna.

The sensitivity and power of an omnidirectional antenna are unfocused; that is, they are spread through a wide volume of space, so the advantage of being able to communicate in all directions is traded off for limited sensitivity and power.

If it is determined that all signals of interest are coming from a definable direction, the omnidirectional antenna can be replaced by a directional or sectoral antenna, which increases sensitivity and power by focusing the beam in the desired direction.

In practice, even omnidirectional antennas take advantage of directionality by focusing their sensitivity and power in the horizontal plane. Rather than waste performance by sending signals into space or into the ground, the horizontal omnidirectional antenna redirects its power and sensitivity from these directions, increasing performance in the horizontal plane.

An omnidirectional antenna is used with a *VIP 110-24* unit for typical VINE networks where a given radio must communicate with a variety of “downstream” radios in various directions.

In point-to-point applications, where the direction of communication is known and fixed, a highly focused directional antenna can be used to provide maximum sensitivity and power. In addition, because of its decreased sensitivity in all directions but the desired one, the directional antenna improves performance by rejecting signals not coming from the desired direction. This provides an effective increase in signal-to-noise performance.

A sector antenna has a wider “spread” than a directional (generally between 60 to 120 degrees) which makes it a cross between an omnidirectional and a directional. This is useful in a point to multipoint configuration where multiple sites are grouped in the same general area. The installer can then make use of the higher sensitivity and power but also take advantage of the wider beam pattern and improved front to back ratio.

Gain

“Gain” specifies the receive and transmit performance of any antenna compared to a standard omnidirectional antenna (“spherical radiator”). The objective of a directional antenna design is to achieve gain, improving sensitivity and effective radiating power to increase range or data rate.

Gain is measured and stated in decibels, abbreviated dB. The decibel is a unit used to indicate the relative difference in power between two signals. For example, a signal 3 dB greater than another signal has twice as much power. The decibel is a logarithmic unit so each doubling of decibels represents a fourfold increase in power. Since 3 dB represents a doubling of power, 6 dB represents a fourfold power increase, 12

dB represents a 16-fold increase, etc. For antenna performance, the unit used is dBi, “i” standing for “isotropic,” which describes the standard spherical radiation pattern.

One type of directional antenna available from UC Wireless is called a “semi parabolic”. This antenna has a gain of 24 dBi, representing power and sensitivity levels 256 times greater than those of a standard omnidirectional antenna.

For omnidirectional coverage from fixed locations, UC Wireless provides collinear antennas. The collinear design achieves gain by increased focus in comparison with the dipole design. The standard collinear antenna used with the *VIP 110-24* provides 9 dBi gain, representing an eight-fold power and sensitivity increase.

Polarization

Another important concept for antenna performance is polarization. An antenna radiates radio waves that vibrate in a specific plane, normally horizontal or vertical. Polarization refers to the restriction of wave vibration to a single plane.

NOTE

Do not confuse polarization with directionality. The plane of wave vibration has nothing to do with the direction of wave propagation. For example, an antenna that focuses its energy in the horizontal plane may be vertically or horizontally polarized.

Designs such as the semi parabolic offer a choice of polarization. Mounting a semi parabolic antenna with the elements horizontal provides horizontal polarization, while mounting the antenna with the elements vertical provides vertical polarization. Similarly, the orientation of the radiating element of the parabolic antenna determines polarization.

In setting up the *VIP 110-24* system, either vertical or horizontal polarization can be used, as long as polarization is the same at both ends of each link. For any given pair of line-of-sight antennas, it is essential that they both have the same polarization. Differences in polarization among antennas – called “cross-polarization” – can reduce signal considerably.

SITE SELECTION

At the high operating frequencies of the *VIP 110-24* system, radio waves travel in a nearly straight line-of-sight path. This is in contrast to the lower-frequency radio waves used for AM broadcasting. These waves bounce between the ionosphere and the earth’s surface to travel long distances and operate over and around obstructions. Higher-frequency radio waves do not behave in this manner and are greatly weakened by substantial obstructions or the absence of a direct path. Simply put, all antennas communicating with each other in the radio network must be able to physically “see” each other.

For this reason, a proper antenna site must meet the following criteria:

1. For optimum performance at maximum range, there must be a clear line-of-sight path among all antennas that communicate directly with each other. At shorter ranges,

some degree of obstruction may be tolerated, but performance in the presence of obstruction is difficult to predict.

2. Elevating one or more of the antennas in the system increases maximum line-of-sight range, called the radio horizon. If antennas are located at a greater range than the ground-level radio horizon, a means must be available for elevating the antennas.
3. All antennas must be properly oriented, and a directional antenna must be carefully aimed at its target antenna to ensure communication at maximum range.
4. All antenna cables attenuate (reduce) signal strength in proportion to their length. Therefore, the distance between the antenna and the radio is limited to a cable length that does not exceed the maximum attenuation tolerated by the system. Since various cable types offer different attenuation levels, maximum length depends on cable type. Generally speaking, because the *VIP 110-24* is an outdoor unit with the output port connected directly to the antenna, cable losses are negligible and the radio will compensate, but there are limits to this compensation. See table 4-2 for sample cables and their respective attenuation values.

Each of these criteria is discussed at greater length in the following paragraphs.

Line-of-Sight Path

Because high-frequency radio waves are attenuated by obstructions, a clear line-of-sight path between antennas is required for optimum performance at maximum range. For shorter ranges, a degree of obstruction may be acceptable. For example, at less than maximum ranges the radio has some ability to “penetrate” trees and other foliage. On the other hand, geographical features (hills) and large buildings are likely to interfere with communications, and antennas must be elevated to “see” each other above such objects.

Because of the uncertainties of radio communication, it is difficult to predict the results in conditions where obstructions exist. The only valid advice is to try the proposed configuration and be prepared to move or elevate the antennas.

Radio Horizon (Maximum Line-of-Sight Range)

In visual terms, the horizon is the point in the distance where an object drops out of sight because it is blocked by the earth’s curvature. If the observer or object is elevated, the visual horizon is extended, that is, the object can be seen at a greater distance before it drops out of view.

The same concept applies to radio signals: The radio horizon is the point in the distance where the path between two antennas is blocked by the curvature of the earth. Like the visual horizon, the radio horizon can be extended by elevating the transmitting antenna, receiving antenna, or both to extend communication range.

The radio horizon can also be extended or shortened by certain phenomena such as refraction due to atmospheric density and temperature inversions. Fog and rain, which reduce signal strength, can also shorten the radio horizon although in the ISM band, this loss is negligible.

A reasonable approximation of the radio horizon based on antenna height can be obtained from the graph in figure 4-1. (Note that this graph does not take atmospheric

effects into account.) To use the graph, set a straight edge so that it crosses the height of one of the antennas in the column on the left and the height of the other antenna in the column on the right. The radio horizon in miles/km is shown where the straight edge crosses the center column.

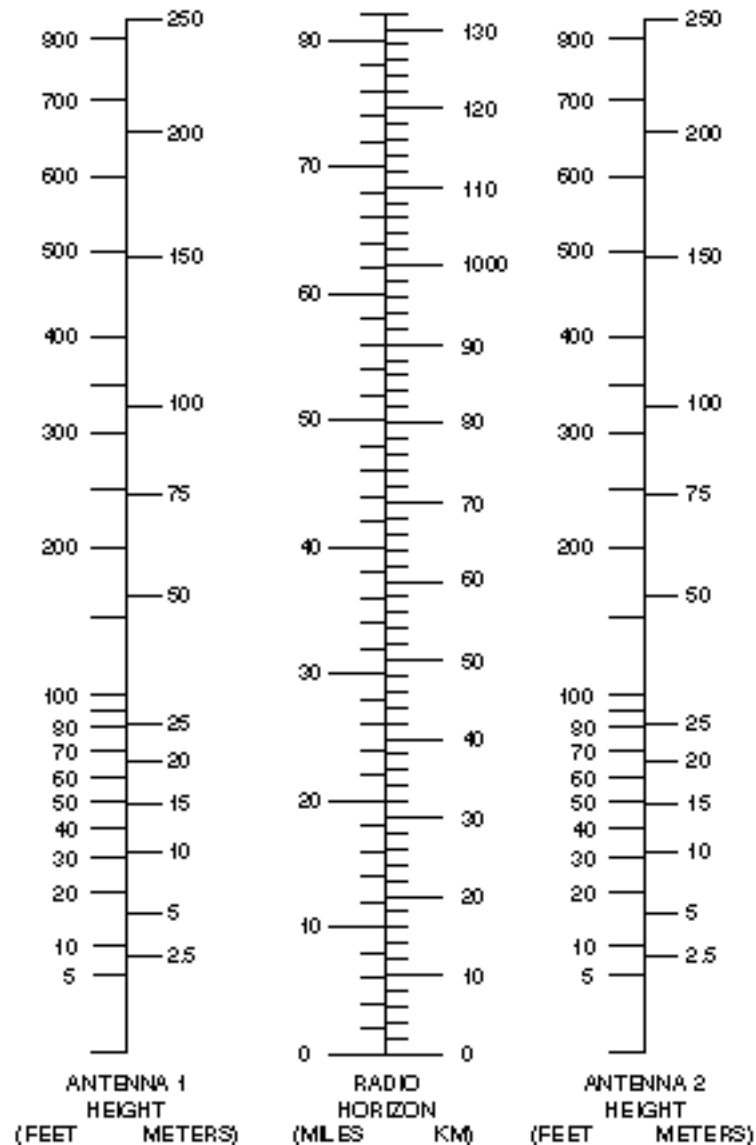


Figure 4-1. Antenna Height and Radio Horizon Graph

If the radio horizon is well within maximum communication range of the system, this graph provides a reasonable guide for antenna height. However, as maximum range of the system is approached, results are less reliable because of atmospheric effects and other unpredictable phenomena. In such cases, the more thorough point-to-point path analysis described in the next section should provide more reliable results.

Point-to-Point Path Analysis

A full point to point analysis should consist of at a minimum, a background noise evaluation of all locations where radios are to be installed, a determination of the minimum antenna height required to obtain a “line-of-sight”, and a calculation of the expected RSS level to be received at each of the locations. The background noise measurement is critical as it gives the operator a preview of the potential performance variations and the feasibility of utilizing a particular radio at a location. For example, if the background noise is found to be at the same level as the radio sensitivity (when set to maximum speed), a tradeoff analysis can be conducted before installation to determine if lowering the data rate will allow the radio sufficient link margin to operate. A line-of-sight is required to insure the best performance from the radio. The calculations below will allow the operator to build towers and other mounting areas to the correct height before the antennas are installed. The calculation of the RSS level is useful for two purposes. The first and primary purpose to calculate the theoretical RSS level at the receive radio is to determine the link margin at the site. This information, when coupled with the background noise measurement, will tell the operator if a link can be established and give a reasonable “a priori” estimate of the performance of the system. In addition to this, the RSS level allows the operator to do a quick check on the integrity of the system installation by verifying that the received RSS level is close to the calculated value.

A background scan is easily accomplished using the built in Spectrum Analysis tool of the *VIP 110-24*. This should be done before any installation of any equipment is completed.

Although the graph of figure 4-1 provides a useful guide to antenna height requirements, a more accurate determination of those requirements can be obtained by means of the analysis described in the following steps.

NOTE

Computer programs available from many vendors can perform portions of this procedure.

Requirements for this procedure are:

1. A topographical map of the installation site.
2. Graph paper, ten divisions per inch or equivalent metric scale
3. Straight edge
4. Calculator

Procedure:

1. On the topographic map, lot the precise location of each antenna site.
2. Draw a line between the sites; this line is the radio path.
3. On the graph paper, establish a vertical axis for elevation and a horizontal axis for distance. It is usually easiest to make the vertical axis in feet or meters and the horizontal axis in miles or kilometers.

4. Following the radio path line on the map, identify all obstructions. Most topographical maps identify geographic information, such as hills and lakes, only. However, vegetation, buildings or other structures that will interfere with radio transmissions must also be included.
5. Plot each obstruction on the graph, marking its elevation and distance from the sites. For dense vegetation such as forests, add 40 to 60 feet (12 to 18 m) to the ground elevation.

An additional increment must be added to the height of each obstruction because of the earth's curvature. For each obstruction calculate this increment using the following formula:

$$d = \frac{d1 \times d2 \times C}{K}$$

Where:

(for US units:)

d	=	additional height increment in feet
d1	=	distance of the obstruction from the first site in miles
d2	=	distance of the obstruction from the second site in miles
C	=	.667 for US units
K	=	refractive index (use a value of 1.33).

(or for metric units:)

d	=	additional height increment in meters
d1	=	distance of the obstruction from the first site in km
d2	=	distance of the obstruction from the second site in km
C	=	.079 for metric units
K	=	refractive index (use a value of 1.33).

Add the "d" value to the height of each obstruction plotted on the graph.

Another increment must be added to the height of each obstruction because of the Fresnel zone (The required increment is 60% of the first Fresnel zone radius). For each obstruction calculate the increment using the formula:

$$d = C \sqrt{\frac{d1 \times d2}{F \times D}}$$

Where:

(for US units:)

- d = 60% of the first Fresnel zone radius in feet
- d1 = distance of the obstruction from the first site in miles
- d2 = distance of the obstruction from the second site in miles
- C = 1368 for US units
- F = 2400 (frequency in MHz)
- D = total path length in miles (d1 + d2).

(or for metric units:)

- d = 60% of the first Fresnel zone radius in meters
- d1 = distance of the obstruction from the first site in km
- d2 = distance of the obstruction from the second site in km
- C = 259 for metric units
- F = 2400 (frequency in MHz)
- D = total path length in km (d1 + d2).

Add the “d” value to the height of each obstruction plotted on the graph.

Determine ideal antenna height by drawing a line on the graph between the sites and across the top of the obstruction heights. Note the elevation at each antenna site.

The following section will show how to calculate the RSS level expected at the radio and to determine the theoretical link margin at the sight.

Determine free-space path loss, using either table 4-1, the graph of figure 4-2, or the formula following figure 4-2.

Table 4-1. Free-Space Path Loss at 2.4 GHz

Distance (miles)	Path Loss @ 2.4 GHz (dB)
1	-104
2	-110
3	-114
4	-116
5	-118
6	-120
7	-121
8	-122
9	-123
10	-124
11	-125
12	-126
13	-126
14	-127
15	-128
20	-130
25	-132
30	-134
35	-135
40	-136
45	-137
50	-138

Distance (km)	Path Loss @ 2.4 GHz (dB)
1	-100
2	-106
3	-110
4	-112
5	-114
6	-116
7	-117
8	-118
9	-119
10	-120
15	-124
20	-126
25	-128
30	-130
35	-131
40	-132
45	-133
50	-134
55	-135
60	-136
70	-137
80	-138

Figure 4-2. Free-Space Path Loss at 2.4 GHz

$$-L = C + 20\log(D) + 20\log(F)$$

Where:

(for US units)

$$\begin{aligned}\sim -L &= \text{loss in dB} \\ C &= 36.6 \text{ for US units} \\ D &= \text{path length in miles} \\ F &= 2400 \text{ (frequency in MHz)}\end{aligned}$$

(or for metric units)

$$\begin{aligned}\sim -L &= \text{loss in dB} \\ C &= 32.5 \text{ for metric units} \\ D &= \text{path length in km} \\ F &= 2400 \text{ (frequency in MHz)}\end{aligned}$$

For example, for a distance of 10 miles

$$\begin{aligned}-L &= 36.6 + 20(1) + 20(3.38) \\ -L &= -124 \text{ dB}\end{aligned}$$

Calculate effective radiated power (ERP) at the transmit antenna. Since the VIP 110-24 is housed in an outdoor enclosure, there is usually no transmission line loss as the antenna is generally connected directly to the radio connector. However, if an additional cable is used between the radio and the antenna cable, the cable loss (attenuation) must be included in order to calculate the correct RSS level.

$$\begin{aligned}\text{WR 2411 output power} &= +23 \text{ dBm} \\ \text{Cable attenuation} &= -2 \text{ dB} \\ \text{Transmit antenna gain} &= +17 \text{ dB} \\ \hline \text{Effective Output Power} &= +38 \text{ dBm}\end{aligned}$$

NOTE: Table 4.2 lists attenuation values for various cables.

Calculate the RSS level at the receive radio using the formula:

$$\text{RSS} = \text{Pt} -$$

Where:

$$\begin{aligned}\text{Pt} &= \text{Output power from the transmit antenna} \\ \text{Lp} &= \text{path loss} \\ \text{Gr} &= \text{Gain of the receive antenna}\end{aligned}$$

For example, for the above system at a distance of 10 miles, with transmit output power of 38 dBm, and a receive antenna gain of 24 dB, the equation would be:

$$\begin{aligned}\text{RSS} &= 38 \text{ dBm} - 124 \text{ dB} + 24 \text{ dB} \\ &= -62 \text{ dBm}\end{aligned}$$

Calculate link margin by subtracting radio sensitivity from the calculated RSS level.

$$\text{Calculated RSS level at receiver} = -62 \text{ dBm}$$

$$\text{Sensitivity of 2411 at 11 Mbps} = -81 \text{ dB}$$

$$\text{link margin} = +19 \text{ dB}$$

This figure, link margin, is the amount of signal received by the radio that is above the minimum required for the radio to meet its performance characteristics. This value is important since it gives the operator an indication of how much signal fade the system can tolerate. Signal fading may be caused by multiple radio paths (reflections) atmospheric conditions such as rain, temperature inversions, fog, etc., and may last anywhere from a few moments to several hours and cause as much as 20 to 30 dB of signal strength loss. Although it is possible to operate a system with a link margin as low as 5 dB, as general rule of thumb it is recommended that all systems have a link margin of better than 20 dB.

Antenna Orientation

Antennas at each end of a communications link must be mounted similarly in terms of polarity, and directional antennas must be carefully oriented towards each other. The choice of polarization – horizontal vs. vertical – is in many cases arbitrary. However, interfering signals from such devices as cellular phones and pagers are generally polarized vertically, and an excellent means of reducing their effect is to mount system antennas for horizontal polarization. Of those antennas in section 4.2 for *VIP 110-24* systems, the directional antennas can be mounted for horizontal or vertical polarization, while the omnidirectional antennas use only vertical polarization. Horizontally polarized omnidirectional antennas are available as a special purchase.

Orientation of directional antennas is critical because their sensitivity is greatly reduced outside a fairly narrow angle. Performance of the system can be seriously degraded by mis-aligned directional antennas.

Cable Loss (Attenuation)

The VIP 110-24 is housed in a watertight enclosure so that it may be mounted in very close proximity to the antenna. Using short cables to connect the radio to the antenna reduces signal losses. Table 4.2 shows loss per 100 feet (30 meters) at 2.4 GHz for typical antenna cable types.

Table 4-2. Loss at 2.4 GHz for Standard Coaxial Cable Types

Cable Type	Loss per 100 ft. (30 m)@ 2.4 GHz
RG-8 A/U	14.4 dB
Belden 9913	8.0 dB
LMR 195	19 dB
LMR 400	6.7 dB

To determine total cable loss for your installation, perform the following calculation:

For US units, multiply length in feet by the loss figure and divide by 100.

For metric units, multiply length in meters by the loss figure and divide by 30.

For example, for a 75-foot length of Belden 9913, the loss is:

$$\frac{75 \times 8.0}{100} =$$

Connector Loss

Loss is introduced with each pair of cable connectors. Attenuation losses of some standard cable types are shown in the following table:

Connector type	Loss per connector
N-Type	0.25 dB
SMA-Type	0.25 dB

The loss of each pair of connectors on all cables must be included to determine the total signal loss (attenuation) between the antenna and ODU.

Other Considerations – Antenna Grounding

WARNING

VERY IMPORTANT INFORMATION

As an elevated metal object with a wire connection below, an antenna is an excellent lightning attractor, and an effective ground must be provided to deflect lightning strikes to ground. An additional advantage of effective system grounding is the minimizing of electrical noise and interference, which can significantly degrade system performance.

Grounding involves providing a good, very low resistance connection from the antenna and radio to earth ground to provide a better path for lightning and electrical noise than that through the equipment. The following points should be taken into account in setting up system grounding:

- The antenna should be mounted on a mast or tower that is well grounded to earth.
- All antenna lead connectors should be correctly installed to provide a good, solid connection to the cable shield.
- Threaded couplings mating antenna lead connectors should be clean and tight; bayonet type connectors should not be used.
- Weatherproof connectors must be used for outdoor connections to prevent corrosion, which will interfere with grounding.
- All power and antenna grounds should be made common at a single point such as an equipment rack, cabinet enclosure chassis, or antenna tower. This single-point ground should have a solid ground connection to earth.
- A surge arrestor or lightning protector should be installed at the point where the antenna cable enters the building or cabinet. The lightning protector should be properly grounded at the single-point chassis ground. Carefully follow the installation instructions provided by the manufacturer of the protection device. An appropriate lightning protector is available from UC Wireless.

INSTALLATION AND SETUP

The *VIP 110-24* units are shipped pre-configured to operate as “repeaters”. It is recommended that an initial check be performed on the bench before a field installation.

For this bench check out you need two *VIP 110-24* units. One of the radios will be configured as the “root” of the network and the other as a “repeater”. The first approach described below uses two terminals connected to the auxiliary port of the radios. The second approach uses the “Ethernet Console Program” to emulate the terminal across an Ethernet connection.

BENCH CHECK OUT (USING RADIO AUXILIARY PORTS)

1. Connect each *VIP 110-24* Auxiliary Port to a terminal, or a PC running a terminal emulation program. Configure the terminal settings as follows:

Baud rate: 9600

Word length: 8 bits

Parity: none

Stop bits: 1

2. Connect each Power Inserter Unit to the respective *VIP 110-24* using a CAT 5 cable as defined in section 3.
3. At the root radio connect the radio Antenna B port (N type connector) to an appropriate 2.4 GHz band antenna using an RF coaxial cable.
4. At the repeater radio connect the radio Antenna A port to an appropriate 2.4 GHz band antenna using an RF coaxial cable.
5. Connect the two Power Inserter Units to a power outlet. Make sure that the power supplies are rated for the appropriate voltage (110 or 220 Vac).

6. The radios will perform power up calibration and diagnostic tests. Verify that radios identify themselves with the correct serial number. At the end of the tests, the radios output the command prompt:

ucw-nnnnn #>

where nnnnn are the last five digits of the radio serial number.

7. Set the “repeater” *VIP 110-24* to its factory default configuration by typing the command:

```
> load factory
> save-configuration
```

8. Configure the second radio (defined as the “root”) by typing the commands:

```
> load factory
> node type=root
> save-configuration
```

9. At the terminal connected to the repeater radio enter the command:

```
> show radio-node
```

Verify that the root node is listed with the correct serial number. The output also displays the transmit RF power and Receive Signal Strength (RSSI) in both link directions.

10. The terminal connected to each radio can be used to further modify the radio’s operating parameters. Section 6 describes the command language used to perform those functions.

BENCH CHECK OUT (USING RADIO ETHERNET CONNECTION)

In order to use the Ethernet connection instead of the auxiliary ports you need the “Ethernet Console Program” (econ) provided in a floppy disk. Copy the “ECON.EXE” file from the floppy to a PC and perform the following steps.

1. Connect the PC Ethernet port to the “To LAN” connector of the Power Inserter Unit of the repeater radio. Use an Ethernet crossover cable if connecting the PC directly to the Power Inserter Unit, or use a straight cable if connecting through a hub.
2. Connect each Power Inserter Unit to the respective *VIP 110-24* using a CAT 5 cable as defined in section 3.
3. At the root radio connect the radio Antenna B port (N type connector) to an appropriate 2.4 GHz band antenna using an RF coaxial cable.
4. At the repeater radio connect the radio Antenna A port to an appropriate 2.4 GHz band antenna using an RF coaxial cable.
5. Connect the two Power Inserter Units to a power outlet. Make sure that the power supplies are rated for the appropriate voltage (110 or 220 Vac).
6. At the PC open a DOS window and invoke the EConsole program by typing:

```
> econ
```

The Ethernet Console program will establish a connection to the repeater radio through the Ethernet port. The radio then outputs the prompt:

```
ucw-nnnnn #>
```

where nnnnn are the last five digits of the radio serial number.

7. Set the “repeater” *VIP 110-24* to its factory default configuration by typing the command:

```
> load factory
> save-configuration
> logout
```

8. Move the Ethernet cable from the repeater power inserter to the power inserter connected to the root radio. At the DOS window invoke once again the Econsole program. Configure the second radio (defined as the “root”) by typing the commands:

```
> load factory
> node type=root
> save-configuration
```

9. Once a radio is configured as the root it will establish a RF communication with the second radio. To verify this connection type:

```
> show radio-node
```

Verify that the two radios are listed with the correct serial numbers. The output also displays the transmit RF power and Receive Signal Strength (RSSI) in both link directions.

10. Once the link is established, Econsole can be used to configure the local or the remote radio. In order to switch the econsole connection, logout of the current connection and reinvoke econsole:

```
> logout
> econ
```

Econsole will list the two radios and give a choice to connect to either. Section 6 describes the command language used to further modify the radio's operating parameters.

APPLICATIONS

VINE Network Topology and Operation

The *VIP 110-24* is the building block of the VINE wireless network. In order to deploy and configure a complete wireless network successfully, some knowledge of the VINE protocol and operation is helpful.

The VINE network topology is a tree. The different node types in the tree are: "root", "repeater", and "leaf". Figure 5.1 below illustrates a possible network. Figure 5.2 shows a graph representation of the same network.

Each *VIP 110-24* in a VINE network operates in a half duplex mode, i.e., it may either transmit or receive at any given time. Transmissions consist of variable length packets. "Outbound" packets flow "downstream" or away from the root node. "Inbound" packets flow "upstream" or towards the root.

The outdoor unit of the *VIP 110-24* is equipped with two antenna ports. Antenna port A is assigned for communications with that node's "parent". Note that each node in the VINE has one and only one parent node. The antenna connected to port A must always be a high gain directional antenna pointing to this upstream node. The root node is the only radio without a parent node.

Antenna port B is assigned for communications with the node's "children". This antenna must provide coverage to all of the node's children. Depending on the geographic location of those children the antenna connected to port B could be an omni, sector, or directional antenna. Leaf nodes do not have children, so no antenna is connected to port B.

Outbound and inbound transmissions must always be assigned to two non-overlapping channel frequencies (this is done automatically by the VINE software but if the default "channel plan" is overridden, this needs to be taken into account).

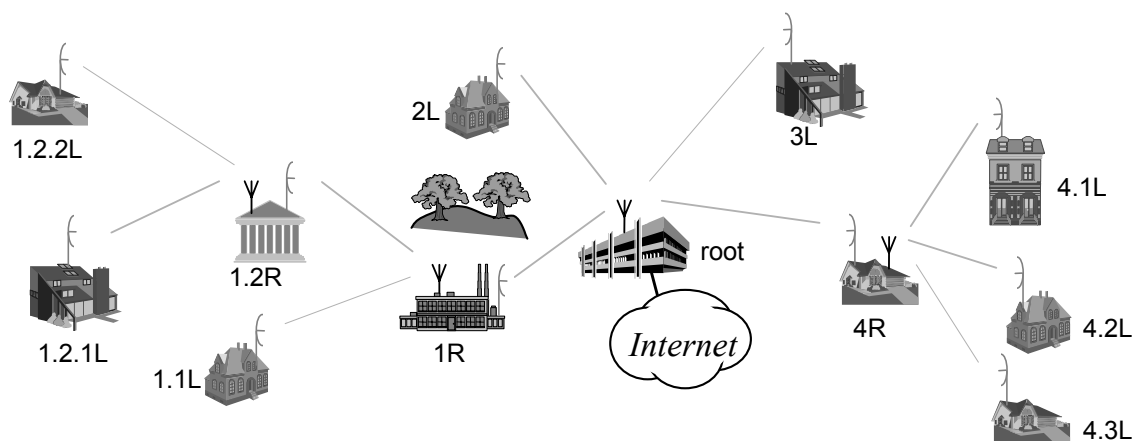


Figure 5.1 – VINE network topology

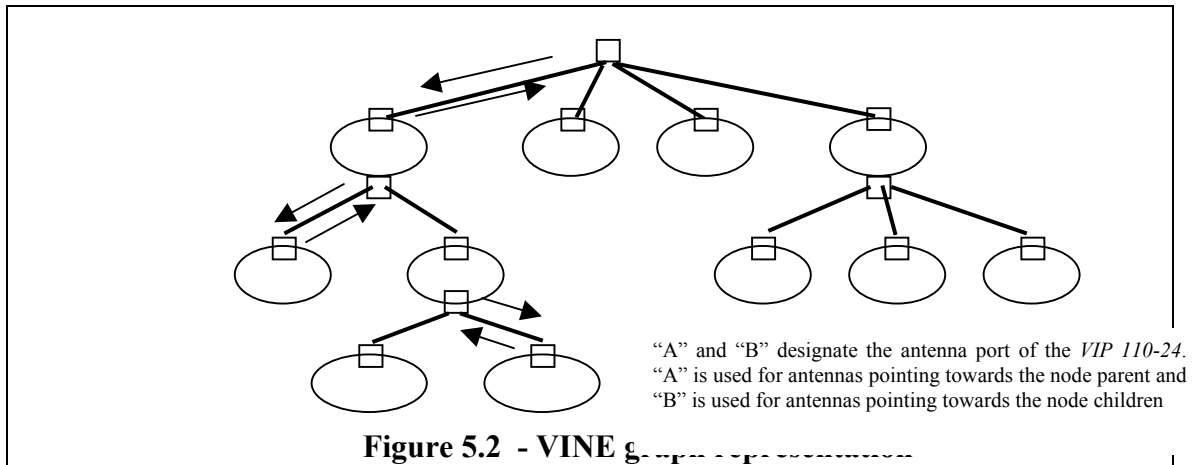


Figure 5.2 - VINE network topology

Node naming convention for figure 5.2

1. Designate the root node as “root”.
2. Number all nodes one-hop away from the root (referred to as its “children”) sequentially starting at 1.
3. Name all the children of each repeater by giving them the parent number and appending a sequential number starting at 1 (use a ‘.’ to separate the parent designator from the child number).
4. Repeat step 3 until all nodes are named. Add an R or an L to the end of the designator to indicate whether the radio is a repeater or a leaf.

With this topology, a transmission within any given “branch” (defined as a parent radio together with its one-hop children) will not interfere with simultaneous transmissions in any other branches. Any two simultaneous outbound transmissions in different branches will be received by the intended nodes due to the high gain antenna attached to the receivers. Similarly, any two simultaneous inbound transmissions in different branches will be received by the intended upstream nodes due to the high gain antenna attached to the transmitters. This scheme is further optimized by having all radios control their output power to achieve no more than the adequate link margin for that particular transmission.

The network in figure 5.1 shows why the inbound and outbound transmissions need to be on different channels. For example, repeater “4R” may perform an outbound transmission, through an omni antenna, at the same time as leaf “3L” performs an inbound transmission to the root. If the inbound and outbound were on the same frequency, there would be a collision at the root.

There may be specific situations where the diversity achieved through the dual frequency operation and antenna directivity would not work. For example, if radios 1R, 1.2R, and 1.2.2L were in a straight line, inbound transmissions from 1.2.2L could reach 1R and interfere with a simultaneous inbound transmission from 1.1L. Those specific cases can be addressed with one or more of the following techniques:

1. Power management: reduce the transmit power from 1.2.2L so that the signal at 1R is significantly below the signal from 1.1L
2. Additional channels: Use the “primary” frequency channels between 1R and its children and the “secondary” channels between 1.2R and its children (see section 5.3)
3. Antenna polarization: use horizontal antenna polarization between 1.2R and its children, and vertical polarization between 1R and its children.

The capability of having multiple simultaneous transmissions in the same geographic area is key to achieve a high network throughput. Within one branch, each parent services all its children by polling each one in turn. The poll/response time is very fast due to the radios fast turnaround and acquisition times. This way, the demand on network resources by children that are not generating or receiving traffic becomes negligible.

Even though repeaters run asynchronously from each other, the complete VINE has an underlying synchronization mechanism that allows repeaters to switch between being a “parent” and a “child” at the appropriate times. Packets can flow up or down the tree, with each radio forwarding the packet through the appropriate Ethernet or RF ports.

The VINE protocol is ideal for bursty traffic that is typical in data communications. The available bandwidth is allocated on demand to the nodes that are “active”. If the network gets congested, there are different Quality of Service parameters that allow the network manager to give priority to certain nodes. Nodes with a “committed information rate” (CIR) will always have access to the committed bandwidth. When those nodes are not using their committed bandwidth, it becomes available to be

shared among all nodes. The unique VINE flow control mechanism adaptively shares this excess bandwidth equally among all active nodes without a CIR.

The root and repeater nodes are always searching for new child nodes. This allows any node to be added to the network by simply pointing the antenna A at the appropriate repeater, and turning the power ON. Within a few seconds the new node establishes contact with the repeater. The network will first authenticate the new node by validating the “Network ID” supplied by the new node. Once authenticated, the new node will be able to transmit and receive traffic in the network.

In an Internet Access application, one of the nodes is connected to the wired Internet. In a VINE network this node is designated as the “anchor”, and it is where a large majority of the traffic will originate and converge. For these applications it is typically desirable to make the root node the anchor.

Ethernet Bridging

Currently the *VIP 110-24* operates as an Ethernet bridge. Future upgrades will add an IP Router option.

As a bridge, the *VIP 110-24* runs in “promiscuous mode”, i.e., it examines all the Ethernet packets that are flowing in the local LAN. Since these Ethernet packets contain a “source” and “destination” address, the radio quickly learns the addresses of all the “local” stations connected to the LAN (all the “source” addresses of packets flowing in the LAN are local).

Each *VIP 110-24* in the VINE periodically transmits the information about the local Ethernet addresses to all other radios. Therefore every *VIP 110-24* holds an Ethernet table that includes one entry for every Ethernet address connected to any of the LANs (this table can be examined with the “show ethernet” command).

With this information on hand, each *WIN Router* examines the destination address of every Ethernet packet in the local LAN and makes one of the following decisions:

1. If the destination address is for a “local” station, discard the packet.
2. If the destination address is connected to a remote radio, queue that packet to be forwarded through the appropriate RF port.
3. If the destination address is unknown, “flood” the packet into the VINE network. The packet will show up at every LAN connected to any radio in the VINE.

Each *VIP 110-24* has capacity to store 500 entries in its Ethernet table. Entries are erased after a certain amount of time to allow for stations to be moved between LANs and not show up in two distinct LANs. The user can control this time-out with the “ethernet” command. If the table ever gets full, entries that have been least used are erased to make room for new entries.

Bridging has two major advantages over routing:

1. There is absolutely no configuration required. The *VIP 110-24* learns about all stations automatically and routes the packets appropriately.
2. All layer 3 protocols (IP, IPX or others) can be bridged.

FIELD INSTALLATION

NOTICE

The antennas for the *VIP 110-24* must be professionally installed on permanent structures for outdoor operations. The installer is responsible for ensuring that the limits imposed by the Federal Communications Commission (FCC) Regulations with regard to Maximum Effective Isotropic Radiated Power (EIRP) and Maximum Permissible Exposure (MPE) are not violated. These limits are described in the following sections.

Antenna Selection and Alignment

The *VIP 110-24* is typically attached to a pole (with the clamp provided) with the antenna connectors facing up. For optimum performance the radio must be mounted in close proximity to the antenna with a cable run typically under 2 meters (6 feet). For the *VIP 110-24*, UC Wireless provides the three antenna types listed below:

Antenna Type	Gain	UCW Model Number
Omnidirectional	9 dBi	OA2.4-9
Yagi	17 dBi	DA2.4-17
Dish Reflector	24 dBi	DA2.4-24

Antennas at each end of the link must be mounted such that they have the same polarization, and directional antennas must be carefully oriented towards each other. The choice of polarization (horizontal vs. vertical) is in many cases arbitrary. However, many potentially interfering signals are polarized vertically and an excellent means of reducing their effect is to mount the system antennas for horizontal polarization.

Of those antennas listed above, the two directional antennas can be mounted for horizontal or vertical polarization, while the omnidirectional antenna can only be mounted for vertical polarization. Horizontally polarized omnidirectional antennas are available upon special request.

When mounting the high gain antenna (24 dBi), the proper antenna alignment is extremely important since the beam-width of the antenna is very narrow. The command:

> monitor-link #N

can be used to report the RSSI level in a link while performing antenna alignment.

Spectrum Analysis and channel selection

Radio operation in unlicensed bands has the potential of suffering from interference from other equipment operating in the same band. The use of directive antennas (used for the upstream connection), greatly reduces the potential for interference. In addition, the *VIP 110-24* includes several features, described below, to identify and overcome sources of interference.

The *VIP 110-24* can be commanded to perform a spectrum analysis of the ISM band and report the results in either a graphical or tabular form. The command:

>spectrum-analysis input=a-antenna dwell=xx

instructs the radio to scan the entire band, dwelling on each channel for a programmable amount of time, and record the highest signal level in that channel. This feature can be used to perform a site survey and identify the best receive channel for the specific link.

With regard to the spectrum analysis output, keep in mind that the *VIP 110-24* receiver RF bandwidth is approximately 18 MHz, but the channels are only 2 MHz apart. For this reason a narrow band transmitter will show up in the spectrum analysis as a lobe with 18 MHz bandwidth. In essence, any channel in the spectrum output that shows a low “noise” level is a good candidate for operation.

Once a potential receive channel has been identified using the spectrum analysis tool, a “timing analysis” may also be used to confirm that the selected channel is indeed clear. The command:

>time-analysis channel=xx input=a-antenna dwell=xx

instructs the radio to dwell on the specified channel for the specified amount of time. After taking several samples the radio displays the signal level detected in that channel over time.

The inbound and outbound channels must be non-overlapping. By default the *VIP 110-24* comes configured with two choices (primary and secondary) for each inbound and outbound links. This “channel plan” can be examined with the command:

>display-configuration

The factory default channel plan is shown below:

	Outbound	Inbound
Primary:	5	25
Secondary	35	15

:

At a repeater or leaf nodes, select the appropriate Outbound channel by first performing a spectrum analysis on antenna A (pointed in the direction of its upstream node). If the spectrum analysis show strong noise in the primary outbound channel (channel 5), then select the secondary outbound channel (channel 35) by typing the command:

```
>rf-receive                                outbound=secondary  
>save
```

At the root and repeater nodes, select the appropriate Inbound channel by first performing a spectrum analysis on antenna B. If the spectrum analysis show strong noise in the primary inbound channel (channel 25), then select the secondary inbound channel by typing the command:

```
>rf-receive                                inbound=secondary  
>save
```

If the primary and secondary choices happen to both have interference, the default channel plan itself may be modified. However this must be done with care to avoid overlapping inbound and outbound channels with other units that may be within line of sight.

These commands change the respective receive channels only. The transmit channels from the radio at the opposite end of each link will be automatically set to the appropriate value when the nodes get attached to the network.

Output Power

Federal Communications Commission (FCC) regulations limit the maximum Effective Isotropic Radiated Power (EIRP) for spread spectrum systems operating in the 2.4 GHz band. Close to the band edges, the output power into the different antennas must be limited to avoid spilling over into the FCC protected band from 2.4835 GHz to 2.500 GHz. The table below takes all these considerations into account and shows the maximum allowed output power.

Maximum Output Power (dBm)				
Channel	Frequency (MHz)	Antenna Gain		
		9 dBi	17 dBi	24 dBi
5	2410.0	23	22	21
6	2412.0	23	23	22
7	2414.0	23	23	22
8	2416.0	23	23	22
9	2418.0	23	23	22
10 to 30		23	23	23
31	2462.0	23	23	20
32	2464.0	17	16	14
33	2466.0	16	14	12
34	2468.0	15	13	10
35	2470.0	15	11	7

Maximum Permissible Exposure (MPE) Limitations

The installer must mount all transmit antennas so as to comply with the limits for human exposure to radio frequency (RF) fields per paragraph 1.1307 of the FCC Regulations. The FCC requirements incorporate limits for Maximum Permissible Exposure (MPE) in terms of electric field strength, magnetic field strength, and power density.

Antenna installations must be engineered so that MPE is limited to 1 mW/cm^2 , the more stringent limit for "uncontrolled environments". The table below specifies the minimum distance that must be maintained between the antenna and any areas where persons may have access, including rooftop walkways, sidewalks, as well as through windows and other RF-transparent areas behind which persons may be located.

Minimum Distance calculation to avoid Antenna Radiation Hazard (exposure of 1 mW/cm^2)			
Antenna Gain (dBi):	9	17	24
Max. Output Power	23	23	23
MPE safe distance (cm)	11*	28*	63*

***NOTE: For fixed location transmitters, the minimum separation distance is 2 m, even if calculations indicate a lower MPE distance.**

UPGRADING THE FIRMWARE.

The firmware in the *VIP 110-24* is stored in a “Flash PROM” and can be easily updated. These updates can be performed over the Ethernet connection to radios wired to that LAN, or, for a working VINE network, across the RF links.

The firmware is distributed in binary form as a file named:

`vipNN_NN.bin`

where NN_NN is the version number.

Firmware upgrades are made available from time to time at the UC Wireless website:

<http://www.ucwireless.com/software/vip11024.shtml>

Once a new firmware file is obtained from the web site, it can be downloaded into the *VIP 110-24* radios using the “download” command as described in section 6.

COMMANDS

CONFIGURATION TECHNIQUES

There are two ways to configure the radio. One uses the auxiliary port at the bottom of the unit and consists of an asynchronous RS-232 link used for issuing configuration commands and monitoring the local radio status and performance. This port is always set to operate with the following parameters:

Baud rate: 9600

Word length: 8 bits

Parity: none

Stop bits: 1

When the unit is mounted outdoors it may be difficult to get access to the RS-232 port at the bottom of the radio. An alternative configuration method uses the Ethernet connection to the radio to perform the configuration. This approach has the advantage that any radio reachable across the Ethernet or the RF link can be configured from a single PC.

In order to use the Ethernet connection to configure the radios the “Ethernet Console Program” (Econsole) needs to be installed at a PC. This PC must be connected to the LAN where one or more *VIP 110-24* is connected. From this PC it is then possible to configure not only the radios directly connected to the LAN but also all other radios reachable through one or more RF hops. Refer to Appendix C for instructions on the installation of Econsole.

After power up the radio performs several diagnostic and calibration tests. At the end of these tests it outputs the command prompt. The default prompt is:

```
ucw-nnnnnn                                     #>
```

where nnnnn are the last five digits of the radio serial number. If a node “name” has been assigned to the node, the prompt will be that name.

The “help” command provides a list of all the commands available. To get more detailed help for a specific command, type “help command-name”. Appendix A lists all the commands available.

The radio keeps a history of several of the previously issued commands. Those commands can be viewed by pressing the up-arrow and down-arrow keys on the keyboard. Any of those previously issued commands can then be edited and reentered by pressing the <Carriage Return> key.

COMMAND SYNTAX

The command interpreter in the *VIP 110-24* is designed to accommodate both a novice as well as an expert operator. All commands and parameters have descriptive names so that they are easily remembered and their meaning is clear. In order to be descriptive however, those commands are sometimes long. As the operator becomes familiar with the command language, typing the complete words could become cumbersome. The *VIP 110-24* command interpreter recognizes any abbreviations to commands and parameter names, as long as they are unambiguous. If an ambiguous command is entered, the radio will output all possible choices.

Commands have the following generic form:

command parameter=value parameter=value

Following is a brief list of syntax rules:

- Words (for commands, parameters, or values) can be abbreviated to a point where they are unambiguous.
- Some commands or parameters consist of compound words separated by an hyphen. With compound words, the hyphen is optional. Additionally each word in a compound word can be abbreviated separately. For example, the following are all valid abbreviations for the command “save-configuration”: “save”, “savec” s-c” “sc”.
- The parameter and value lists are context sensitive, i.e., in order to solve ambiguities the command interpreter only considers parameters valid for current command, or values valid for the current parameter.
- The arguments “parameter=value” must be entered with no blank spaces on either side of the ‘=’ sign. Those arguments (parameter/value pairs) can be listed in any order.
- Even though parameters can be listed in any order, there is a “natural” order known by the command interpreter. This allows the user to specify parameter values without having to type the parameter names. For example the command
>spectrum-analysis input=a-antenna display=table

can be entered as (using abbreviation rules as well):

>spa a t

- Using the preceding rule, for commands that have a single argument, the “parameter name” part of the argument is always optional, i.e., you can enter:

>command value

For example the command:

>show-tables table=radio-nodes

can be shortened to any of the following:

>show-tables

radio-nodes

>show

radio

>show rn

- Not all parameters associated with a command need to be specified. Depending on the command, when a parameter is omitted it either assumes a default value or keeps the last value assigned to that parameter.

The following sections describe the various commands grouped according to their functionality as follows:

A summary list of all commands and default values are contained in Appendix A.

CONFIGURATION MANAGEMENT COMMANDS

A “radio configuration” consists of a set of programmable parameters that define the radio operation with regard to a variety of operating modes. The radio holds four configurations at all times, identified as “current”, “main”, “alternate”, and “factory”.

The “main” and “alternate” configurations are both stored in non-volatile memory. They can be loaded into the “current” configuration with the “load” command. On power up the radio loads the “main” configuration from non-volatile memory into the current configuration.

The “current” configuration is the set of parameters currently being used and can be modified by the operator through several commands. This configuration is volatile. If the current configuration has been modified it should be saved using the “save” command. Otherwise the modifications will be lost if power is removed.

The “factory” configuration can not be modified by the operator and is used to return the radio to the factory default condition. It is useful as a starting point to create a customized configuration.

The access to change the radio configuration can be password protected. This password is set by the user with the “change-password” command. Once a password is set, issue the “lock” command to prevent any unauthorized changes to the configuration. Once locked, the configuration can only be modified by issuing the “unlock” command with the correct password.

When the configuration is unlocked, the radio prompt ends with the characters ‘#>’ to remind the user that the configuration is unlocked. In locked mode the prompt does not include the ‘#’ character. Once a password is set, the radio will automatically lock the configuration after 10 minutes without any commands being issued.

WARNING

The *VIP 110-24* is shipped with no password. If the “change-password” command is issued make sure you do not forget the password. Once locked, without a password, the radio must be returned to the factory to be unlocked.

The configuration management commands are listed below:

load-configuration

source=main or *alternate* or *factory*

Loads the specified configuration into the current set of parameters controlling the radio operation. If no source is specified it defaults to the “main” configuration.

Examples:

```
> load-configuration source=factory
> load
```

save-configuration

destination=main or *alternate*

Saves the current set of radio operating parameters into one of the two non-volatile configurations. If the destination is not specified it defaults to main.

Examples:

> **save-configuration destination=alternate**
> **save**

display-configuration

source= current or main or alternate or factory

Displays all the parameter values for the specified configuration. If the source is not specified it defaults to current.

Examples:

> **display-configuration source=current**
> **display**

change-password

enable-configuration="ASCII string"

This command allows the user to set or change a password used to “lock” and “unlock” access to the commands that change the radio configuration. The *VIP 110-24* is shipped with no password which allows access to all commands. Once a password is set and the configuration is locked, the password is needed to unlock the access to those commands.

Examples:

> **change-password enable-configuration=bh7g8**

WARNING

The *VIP 110-24* is shipped with no password. If the “change-password” command is issued make sure you do not forget the password. Once locked, without a password, the radio must be returned to the factory to be unlocked.

lock

This command locks the access to all the commands that can alter the radio configuration. Once locked use the “unlock” command to regain access to those commands. Note that a password must be set prior to the “lock” command being issued (the radios are shipped with no password), otherwise the lock command has no effect. If a password is set, the radio automatically “locks” the configuration at the end of 10 minutes with no command activity.

unlock

enable-configuration="ASCII string"

This command, with the correct password, unlocks the access to the commands that allow the radio configuration to be altered.

Examples:

> unlock enable-configuration= bh7g8

MAJOR CONFIGURATION PARAMETERS

These commands change several operating parameters of the radio that are part of the radio “configuration”. When entering commands with multiple parameters, if a parameter is not included, that parameter keeps its current value.

node

network-id=0...4,294,967,295

The network ID is a network wide value that needs to be the same for all the nodes in the network. When a new node attempts to attach to the network, it transmits

the network ID. The parent radio checks if this network ID matches its own network ID. If this check fails the new node is not admitted into the network.

Examples:

> **node network-id=67903**

name="ASCII string"

Gives the node a meaningful name for further reference. The name can be up to 12 characters. This name will be used as the command prompt. It is also used to identify the node in a variety of commands and displays.

Examples:

> **node name=main_bank02**

type=root or repeater or leaf

The node type defines the operation of the radio within the VINE network (see section 5.2). The type can be set to one of three values:

root: The root radio is the logical hub of the network and controls the network timing. There must be only one root in a VINE network.

repeater: The repeater nodes are subsidiary to the root or other repeaters. A repeater node acts as a slave to its parent and as a master to its children. Repeaters also keep searching for new child nodes by performing “new node polls”.

leaf: A leaf node is just like a repeater except that it does not perform new node polls. This results in a slight optimization of network timing.

Examples:

> **node type=leaf**

anchor=yes or no

Some network applications have the characteristic that the traffic to all radios is originated at a single node in the network. That same node is also the destination of all traffic transmitted by all other radios. This is the case for an Internet Access application for example. For these applications this special node should be designated as the “anchor” (only one node in the network should be the anchor). The anchor node enforces the receive flow rates (specified with the “min-flow-rate” and “max-flow-rate” commands) for each radio.

It is generally more efficient to make the anchor node the same as the root node although it is not necessary to do so.

Examples:

> **node anchor=yes**

min-flow-rate

transmit-kbps=1...1000

Specifies the minimum data rate that the radio will accept from the Ethernet port to be offered into the VINE network, even during congested periods. This is equivalent to the “Committed Information Rate (CIR)” in a frame relay environment.

receive-kbps=1...1000

Specifies the minimum data rate that the anchor radio will accept from its Ethernet, addressed to this specific node, even during congested periods. This is equivalent to the “Committed Information Rate (CIR)” in a frame relay environment.

Examples:

> **min-flow-rate transmit-kbps=500**

max-flow-rate
transmit-kbps=1...10000

Specifies the maximum data rate that the radio will accept from its Ethernet port to be offered into the VINE network, even during idle periods.

receive-kbps=1...10000

Specifies the maximum data rate that the anchor radio will accept from its Ethernet, addressed to this specific node, even during idle periods.

Examples:

> **max-flow-rate receive-kbps=1024**

rf-receive-channel
outbound= primary or secondary

Selects the channel to be used for receiving outbound packets transmitted by this radio’s parent. The mapping into actual channel numbers are specified in the “channel plan”. The “primary” channel should be the first choice. The secondary channel is provided in case there is interference in the primary choice.

inbound= primary or secondary

Selects the channel to be used for receiving inbound packets transmitted by this radio's children. The mapping into actual channel numbers are specified in the "channel plan". The "primary" channel should be the first choice. The secondary channel is provided in case there is interference in the primary choice.

Examples:

> **rf-receive-channel inbound=primary**

rf-channel-plan

inbound-primary=5..35

inbound-secondary=5..35

outbound-primary=5..35

outbound-secondary=5..35

The channel plan sets the receive channel choices available to this node for outbound or inbound communications. The two outbound channels are also used by radios configured as "root" or "repeater" to transmit "New Node Polls" in order to acquire new children. The factory default channel plan is shown below:

	Outbound	Inbound
Primary:	5	25
Secondary	35	15
:		

Normally this would not be modified. However, if both primary and secondary choices are not suitable, each entry in the channel plan can be modified with this command. When modifying the channel plan, several guidelines need to be considered:

1. The outbound channel number corresponding to the channel selected by the `rf-receive` command must match one of the outbound channel numbers on this node's parent channel plan.
2. All channels must be non-overlapping (see appendix A for a list of non-overlapping channels).

Examples:

```
> rf-channel-plan inbound-primary=10
```

```
rf-nnp-tx-power  
primary-tx-power-dbm=0..23
```

```
secondary-tx-power-dbm=0..23
```

A node configured as a root or repeater periodically transmits “new node poll” packets in the two outbound channels defined in the channel plan. This command sets the power used for these transmissions.

Examples:

```
> rf-nnp-tx-power primary=15
```

rf-to-parent

This command sets the speed and transmit power used in the RF transmissions from this node to its parent. Note that the third RF parameter, rf channel, is always selected by the parent using the rf-receive command.

mode=automatic or manual

In automatic mode, when this radio attaches to the network, it communicates the desired link margin to the parent radio. The parent radio measures the local noise floor and computes the optimum speed and power required to achieve the desired link margin. The parent then transmits those parameters to this radio which adjusts the speed and power accordingly.

In manual mode the speed and transmit power are determined by the parameters below which are stored in this radio configuration.

margin-db=0..40

This link margin is used in automatic mode only. It represents the desired signal to noise ratio at the receiver (parent radio).

speed-mbps= 1, 2, 5.5, 11

RF speed used in transmissions to the parent radio when the mode is manual. This value is ignored if the mode is automatic.

power-dbm=0..23

RF power used in transmissions to the parent radio when the mode is manual. This value is ignored if the mode is automatic.

Examples:

> rf-to-parent mode=manual speed=2

rf-from-parent

This command sets the speed and transmit power used in the RF transmissions from the parent to this node. Note that the third RF parameter, rf channel, is always selected by this node using the rf-receive command.

mode=automatic or manual

In automatic mode, this radio measures the local noise floor and computes the optimum speed and power required to achieve the desired link margin. The radio then transmits those parameters to the parent which adjusts the speed and transmit power accordingly.

In manual mode the speed and transmit power are determined by the parameters below. Those parameters are stored in this radio configuration and communicated to the parent when the radio gets attached to the network.

margin-db=0..40

This link margin is used in automatic mode only. It represents the desired signal to noise ratio at the receiver (this radio).

speed-mbps= 1, 2, 5.5, 11

RF speed used in transmissions from the parent radio when the mode is manual. This value is ignored if the mode is automatic.

power-dbm=0..23

RF power used in transmissions from the parent radio when the mode is manual. This value is ignored if the mode is automatic.

Examples:

> rf-from-parent mode>manual speed=2

orphan-reset

timeout-sec=30..3600

After power up, a non-root radio attempts to get attached to a parent radio by responding to a “new node poll” transmitted periodically by the root and all repeater radios. If a radio fails to get attached (or drops an existing attachment), it will perform a complete reset after the timeout specified in this command.

This feature is useful if a command is issued to a remote radio changing its parameters in such a way that breaks the link to its parent. In that case the remote radio will drop its attachment to the network, wait for the “orphan-reset-timeout” and then perform a reset. As a result, the radio reverts to the saved configuration allowing it to get reattached to the network.

Examples:

> orphan-reset timeout-sec=200

BRIDGE MANAGEMENT COMMANDS

Bridge management commands set and display the specific operating characteristics relating to the operation of the radios as a network.

ethernet

timeout-sec=5..1800

Sets the time the radio will retain, in its internal table, Ethernet addresses obtained from the network.

multi-cast-timeout-sec=5..3600

Sets the time the radio will retain, in its internal table, Ethernet multi-cast addresses obtained from the network.

Examples:

> **ethernet multi-cast-timeout-sec=3000**

show-tables

table=radio-nodes or ***ethernet-stations*** or ***counters*** or ***flow-control*** or ***link-speeds*** or ***parents*** or ***all***

fomat=normal or ***basic*** or ***times***

Displays information about the overall VINE network. The “show-tables table=ethernet-stations” command can be a two part command with an option of “format”.

The “radio-node” table displays the system start time, current radio configuration, and information about all radios currently in the network.

The “ethernet-stations” table contains information about all the known ethernet stations in the network.

The “counters” table contains various statistics.

The “flow-control” shows the flow control settings.

The “link-speed” shows the link speeds in the individual RF links.

Under the “show-tables table=ethernet-stations” command, the “normal” format contains a detailed output of the ethernet stations including the number of packets coming to and going from the local radio and the number of packets being forwarded to and from the local radio, packets lost, and data rate. (*Not yet impemented*)

Under the “show-tables table=ethernet-stations” command, the “basic” format lists the number of packets coming to and going from the local radio and the number of packets being forwarded to and from the local radio.

Under the “show-tables table=ethernet-stations” command, the “times” format shows the multicast status, when each radio was added, and the idle status.

Example:

```
>show-tables                                table=radio-nodes
>show-tables table=ethernet format=basic
```

INSTALLATION AND LINK MONITORING COMMANDS

spectrum-analysis

input=a-antenna or b-antenna

display=graph or table

dwell-time-ms=0..1000

This command performs a scan of all the channels in the band, dwelling on each channel for the specified amount of time (defaults to 20 milliseconds). While on each

channel it measures the RSSI for that channel and stores its peak value. It then displays the data collected in a graphical or table formats (defaults to “graph”).

During the test the RF input into the radio can be selected between one of the two antennas.

Example:

```
>spectrum-analysis                                input=b-antenna
>spectrum-analysis input=a-antenna display=table dwell-time=500
```

time-analysis

channel=5..35

input=a-antenna or b-antenna or test-oscillator

display=graph or table

dwell-time-ms=1, 2, 5, 10, 20, 50, 100, 200, 500

This command measures the RSSI for a single channel over a period of time. Each “sample” consists of the maximum RSSI measured during the dwell time specified (defaults to 20 milliseconds). After collecting 60 samples the RSSI values are displayed graphically or numerically (defaults to “graph”).

In this test the RF input into the radio can be selected between one of the two antennas.

Example:

```
>time-analysis                                input=b-antenna
>time-analysis input=a-antenna display=table dwell-time=500
```

monitor-link

node= node-name or #node-number

clear=on or off

This command continuously displays link statistics with any of this radio's direct neighbors. The neighbor radio is identified either by the node name or by the node number (as displayed with the "show" command) preceded by the # character. The "clear=on" parameter clears the current statistics.

Examples:

>monitor-link

node=main_bank02

>monitor-link clear=on

test-rf-link

command= status or start or stop

node=node-name or #node-number

This command can be used to perform an RF link test between this radio and a radio specified by the "node" parameter. The node is identified either by the node name or by the node number (as displayed with the "show" command) preceded by the # character. Once the test is started the radio continuously generates and transmits test packets addressed to the specified node. The remote node echoes those packets back. The status of the test (number of packets transmitted and received) can be viewed by issuing the command "test-rf-link status".

Examples:

```
>test-rf-link          command=start          node=          main_bank02  
>test-rf-link command=status
```

EVENT LOGGING COMMANDS

The *VIP 110-24* keeps track of various significant events in an “event log”. This event log holds up to 500 events. The first 100 entries in the log are filled sequentially after power up and are not overwritten. The remaining 400 entries consist of the last 400 events recorded. All events are time-tagged with system time.

Events are classified in different categories from level 0 (catastrophic error) to 7 (information).

display-log

length=1..500

region=end or *beginning* or *all*

id=0..150

min-level=0..7

max-level=0..7

This command outputs to the terminal the specified “region” of the event log. The “length” parameter specifies the number of events to output (defaults to 10). The remaining parameters provide filters to leave out specific events. If the “id” parameter is specified, only the event identified by that id will be displayed. The “min-level” and “max-level” settings allow the user to display only the events with the specified category range.

Examples:

>display-log

region=all

>display-log region=all length=300 min-level=2 max-level=6

clear-log

Clears the contents of the system event log, including the first 100 events.

max-event

Sets the event severity level that should be saved or displayed. These two parameters are saved as part of the configuration

save=0..7

Only events of the specified level or below will be saved in the event log.

print=0..7

Events of the specified level or below will be output to the terminal as they occur.

Examples:

>max-event print=6

display-reboot-reasons

Displays the events that caused the radio to reboot the last four times. The time tag in these events is the time the radio was up since it was rebooted, not the time of day.

clear-reboot-reasons

Clears the non-volatile memory with the log of the reboot reasons. After a code upgrade it is recommended to clear the reboot reasons since the pointer in non-volatile memory pointing to the reason message may no longer be valid.

FILE UTILITIES

The *VIP 110-24* maintains a file system that allows multiple programs to be stored in either non-volatile flash PROM or volatile RAM. New programs can be downloaded into the *VIP110-24* memory through the auxiliary port, through the Ethernet port, or to remote radios across RF links in a VINE network.

One of the programs in flash PROM is designated as the default program to run after reboot. On power up that program is copied from PROM into RAM and the code runs out of RAM.

Any program can be invoked with the command “bootload-file” without making it the default file. This is useful when upgrading the software over an RF link as a way to ensure that the new code is working correctly before making it the default.

list-files

format=short or full

Lists all the files currently stored in flash PROM and RAM, their size, the sectors occupied and the MD5 checksum. It also indicates which of the files is the default program. Files stored in flash PROM have the flash/ prefix. Files stored in RAM have the tmp/ prefix.

copy-file

input-file=filename

output-file=filename

Copies the input-file into the output-file.

delete-file

filename=filename

Deletes the specified file from RAM or Flash PROM.

Examples:

>delete-file flash/vip01_03

download-file

output-file=flash/filename

or

tmp/filename

method=inline or ***binary***

Downloads a program file from a PC to the *VIP 110-24*.

To download a file through the Ethernet port or across RF links you need to be running the Econsole program on a PC attached to a radio through the Ethernet port. In this case the program file must be in binary format (with extension .bin) and must reside in current directory (where the command econ was invoked from). The program file is transferred to the *VIP 110-24* and it is stored in the radio memory under the same name. Note that the “.bin” extension is not needed in the command. The download “method” to use must be “binary”

If the download is performed from a terminal connected to the Auxiliary port, the file is in ASCII format and has the extension .dwn. The download method must be “inline”. After the command is invoked, the user must initiate the transfer of the file from the terminal.

Examples:

>download

flash/vip01_04

In this case the file “vip01_04.bin” must exist in the PC current directory and will be transferred to the VIP110-24 flash PROM.

console-speed-bps***baud-rate-bps=9600 or 19200 or 38400 or 57600 or 115200***

Sets the Auxiliary port of the radio to the specified baud rate. This setting is not saved in the radio configuration, the auxiliary port always powers up set for 9600 baud.

This command is useful to speed up the download process over the auxiliary port. Before issuing the download command, use this command to change the radio console speed to the highest baud rate supported by the PC. Then change the terminal settings to match the radio speed. Issue the download command described above and initiate the transfer at the terminal.

bootload-file***filename=flash/filename***

Executes the specified file. The file is first copied into RAM and then the program is executed out of RAM.

MISCELLANEOUS COMMANDS***date***

The *VIP 110-24* will set the internal radio date and time automatically by decoding Network Time Protocol (NTP) packets in the Ethernet LAN. The “zone” parameter specified with the “date” or “time” command will then be used to display the date/time in local time. The “zone” value is saved as part of the radio configuration.

If NTP packets are not available, the user can initialize the radio date and time with either the “date” or “time” commands. The parameters for both commands are identical, but the parameter order is different. The date command can be entered as:

> date 16-may-2000 10:32:06

date=day-month-year

Sets the date used by the radio. The day / month / year parameter may be separated by any valid separator (‘-‘ ‘/’ etc.)

time=hh:mm:ss

Sets the radio time in hours, minutes and seconds. Use colons to separate the three fields.

zone=zone-code or offset

Sets the time zone to be used by the radio to translate the NTP time to local time. It can be specified by an offset from GMT (-0800 or +0200 for example), or as a “zone-code”. The valid “zone-codes” and the respective offsets are shown below:

Zone	zone code	offset
Pacific Standard Time	PST	-0800
Pacific Daylight Time	PDT	-0700
Mountain Standard Time	MST	-0700
Mountain Daylight Time	MDT	-0600
Central Standard Time	CST	-0600
Central Daylight Time	CDT	-0500
Eastern Standard Time	EST	-0500
Eastern Daylight Time	EDT	-0400
Greenwich Mean Time	GMT	0000

time

time=hh:mm:ss

date=day-month-year

zone=zone-code or offset

This command is identical to the “date” command explained above except for the order of the parameters. It allows the time and date to be entered as:

> time 10:32:06 16-may-2000

help [command-name]

If no command is specified, displays the complete list of commands. If a command is specified it displays the valid parameter and corresponding values for that specific command.

Examples:

>help

rf-channel-plan

history

Displays the previous commands entered.

reboot

Resets the radio causing the software to perform a complete start up sequence.

This is equivalent to power cycling the radio off and on.

version

Displays the radio model and software version.

logout

Closes the current Econsole session.

APPENDIX A – COMMAND SUMMARY (ALPHABETICAL)

This appendix lists all commands in alphabetical order. The table contains the functional group of the command. Further information about the command can be found in appendix B or section 6.

Command	Parameters	Functional Group
Bootload-file	filename	File Utilities
change-password	enable-configuration	Configuration Management
clear-log		Event Logging
Console-speed-bps	baud-rate-bps	File Utilities
copy-file	input-file output-file	File Utilities
Date	date time zone	Miscellaneous
delete-file	filename	File Utilities
Display-configuration	source	Configuration Management
Display-log	length region id min-level max-level	Event Logging
download-file	output-file method	File Utilities
Ethernet Ethernet	timeout-sec multicast-timeout-sec	Bridge Management
Help	command	Miscellaneous
History		Miscellaneous
list-files	format	File Utilities

Command	Parameters	Functional Group		
load-configuration	source	Configuration Management		
Lock		Configuration Management		
logout		Miscellaneous		
Max-event	save print	Event Logging		
Max-flow-rate	transmit-kbps receive-kbps	Major Parameters	Configuration	
Min-flow-rate ⁽¹⁾	transmit-kbps receive-kbps	Major Parameters	Configuration	
monitor-flow		Installation monitoring	and	Link
monitor-link	node clear	Installation monitoring	and	Link
Node	network-id name type antenna anchor	Major Parameters	Configuration	
orphan-reset	timeout-sec	Major Parameters	Configuration	
reboot		Miscellaneous		
rf-channel-plan	inbound-primary inbound-secondary outbound-primary outbound-secondary	Major Parameters	Configuration	
rf-from-parent	mode margin-db speed-mbps power-dbm	Major Parameters	Configuration	
rf-nnp-tx-power	power-dbm-primary power-dbm-secondary	Major Parameters	Configuration	

Command	Parameters	Functional Group		
rf-receive-channel	outbound inbound	Major Parameters	Configuration	
rf-to-parent	mode margin-db speed-mbps power-dbm	Major Parameters	Configuration	
Save-configuration	destination	Configuration Management		
show-tables	table format	Bridge Management		
spectrum-analysis	input display dwell-time-ms	Installation monitoring	and	Link
test-rf-link	command node	Installation monitoring	and	Link
Time	time date zone	Miscellaneous		
Time-analysis	Channel input display dwell-time-ms	Installation monitoring	and	Link
Unlock	enable-configuration	Configuration Management		
Version		Miscellaneous		

APPENDIX B - COMMAND SUMMARY (FUNCTIONAL)

This appendix lists all commands organized in the respective functional groups. Parameters that are part of the radio configuration are identified by having an entry under the “Factory Configuration” heading. When entering a command, if a parameter that is part of the radio configuration is omitted, the value for that parameter is not modified.

For commands that are not part of the radio configuration, if a parameter is omitted, the value for that parameter defaults to the value indicated in bold.

Configuration Management Commands

Command	Parameters	Values
load-configuration	source	main alternate factory
save-configuration	destination	main alternate
Display-configuration	source	current main alternate factory
Change-password	enable-configuration	<string>
Lock		
Unlock	enable-configuration	<string>

Major Configuration Parameters

Command	Parameters	Values	Factory Configuration
Node	network-id	0..4,294,967,295	0
	name	ASCII string	ucw-serial no.
	type	root repeater leaf mobile	repeater
	antenna	single dual	single
	anchor	yes no	no
min-flow-rate	transmit-kbps	1..1000	10
	receive-kbps	1..1000	10
max-flow-rate	transmit-kbps	1..10000	1000
	receive-kbps	1..10000	1000
rf-channel-plan	inbound-primary	5..35	25
	inbound-secondary	5..35	15
	outbound-primary	5..35	5
	outbound-secondary	5..35	35
rf-receive-channel	outbound	primary secondary	primary
	inbound	primary secondary	primary

Command	Parameters	Values	Factory Configuration
rf-to-parent	mode	automatic manual	manual
	margin-db	0..40	20
	speed-mbps	1, 2, 5.5, 11	11
	power-dbm	0..23	18
rf-from-parent	mode	automatic manual	manual
	margin-db	0..40	20
	speed-mbps	1, 2, 5.5, 11	11
	power-dbm	0..23	18
rf-nnp-tx-power	primary-power-dbm	0..23	18
	secondary-power-dbm	0..23	18
Orphan-reset	timeout-sec	30..3600	600

Bridge Management Commands

Command	Parameters	Values	Factory Configuration
ethernet	timeout-sec	5..1800	30
	multi-cast-timeout-sec	5..3600	600
show-tables	table	radio-nodes ethernet-stations counters all	

Installation and Link Monitoring Commands

Command	Parameters	Values
spectrum-analysis	input	a-antenna b-antenna
	display	graph table
	dwell-time-ms	1...1000 (def: 20)
time-analysis	channel	5..35
	input	a-antenna b-antenna
	display	graph table
	dwell-time-ms	1, 2, 5, 10, 20 , 50, 100, 200, 500
monitor-link	node	node-name or #node-number
	clear	no yes
test-rf-link	command	status start stop
	node	node-name or #node-number

Event Logging Commands

Command	Parameters	Values	Factory Configuration
Display-log	length	1...500 (def: 10)	
	region	end beginning all	
	id	0...150	
	min-level	0...7 (def: 0)	
	max-level	0...7 (def: 7)	
clear-log			
max-event	save	0..7	5
	print	0..7	3
Display-reboot-reasons			
clear-reboot-reasons			

File Utilities

Command	Parameters	Values
list-files	format	short full
copy-file	input-file	filename
	output-file	filename
delete-file	filename	filename
download-file	output-file	filename
	method	binary inline
Console-speed-bps	baud-rate-bps	9600, 19200, 38400 57600, 115200
bootload-file	filename	filename

Miscellaneous Commands

Command	Parameters	Values	Factory Configuration
Date	date	dd-mmm-yyyy	GMT
	time	hh:mm:ss	
	zone	offset or code	
Time	time	hh:mm:ss	GMT
	date	dd-mmm-yyyy	
	zone	offset or code	
Help	command		
History			
Reboot			
Version			

Logout

APPENDIX C – CHANNEL FREQUENCY ASSIGNMENT

Channel	Frequency (GHz)	Channel	Frequency (GHz)	Channel	Frequency (GHz)
5	2.410	15	2.430	25	2.450
6	2.412	16	2.432	26	2.452
7	2.414	17	2.434	27	2.454
8	2.416	18	2.436	28	2.456
9	2.418	19	2.438	29	2.458
10	2.420	20	2.440	30	2.460
11	2.422	21	2.442	31	2.462
12	2.424	22	2.444	32	2.464
13	2.426	23	2.446	33	2.466
14	2.428	24	2.448	34	2.468
				35	2.470

Number of Non-Overlapping Channels	Suggested Channel Allocation	Frequency Separation (MHz)
3	5, 20, 35	30.0
4	5, 15, 25, 35	20.0

APPENDIX D – ETHERNET CONSOLE PROGRAM

EConsole v1.0

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document version : 1.06

Short description

The ethernet console program was developed in order to accommodate the remote configuration of a radio, i.e. the configuration in cases where the physical access to the radio is not feasible, or it is cumbersome. The software consists of two parts: the client and the server. The client runs on the administrator's Windows PC, while the server runs on the radio.

The communication is done via a TCP-like protocol. There is an acknowledgment for every packet that is sent, as well as a retransmission mechanism when a packet gets lost.

Each radio allows multiple sessions, i.e. more than one clients can be connected concurrently to the same server (radio). Nevertheless, for performance reasons it is not recommended to have more concurrent sessions than they are really needed, and definitely not more than the maximum number which currently is 4.

System requirements

Currently the only supported platform for the client is Microsoft Windows operating system. A client for Unix/Linux is still under development. NetBIOS must also be installed, as well as the WinPCap library.

- Win95, win98, Windows ME, WinNT, Windows2000
- NetBIOS installed
- WinPCap installed

Note: With regard to Windows NT platform, the code has been tested with versions 4.0, or newer.

Installation

In order to install the WinPCap library, if not already installed, just click on the WinPCap.exe. Support and updates for this library can be found at <http://netgroup-serv.polito.it/winpcap/>. It is strongly suggested to uninstall older versions of the library and reboot the machine before installing the new one. To start the Econsole, simply open a MS-DOS console and type *econ*. For available command line arguments, please read the following section.

Included files

- *README.doc* The file that you are reading
- *econ.exe* The EConsole client

- *WinPCap* The Windows installer for the WinPCap library
- *input_script.txt* A sample input script file, that contains a list of radio commands.

Input arguments

You can provide the following arguments in the command line, even though none of them are required.

Input file

There are two sources for the input commands: the keyboard, or a text file. The second option is useful when you are running the same set of commands periodically, so you want to avoid retyping them every time you want to execute them. If there is an input file in the command line, then the keyboard will be deactivated and only the function keys will be available. If the specified file cannot be found, the application will be terminated.

example:

C: > econ -i input.txt

Sample input file:

help

this is a comment - note that the character # must appear as the fist character

time

date

the following is a local command

. delay 10

time

. delay 1.5

version

logout

As you probably noticed from the above file, all the lines are interpreted as radio command, unless:

- a) They start with the character # which implies a comment
- b) They start with the character . which implies a local command. Currently there is only one local command, namely the *delay secs*

Important note: All the input scripts should end with the *logout* command. Since all the commands are terminated with the new line character, there must be one command per line and after the final *logout* command you must have an extra empty line.

Output file

When you want to capture the output of a session into a text file, you can pass the filename as an argument. If the file does not exist it will be created, otherwise it will be overwritten. If you prefer to append rather than overwrite its contents, you should use the *-a* option.

example:

```
>econ -o output.txt
```

Radio MAC address

If you are interested in a specific radio, you can pass its MAC address and let the client ignore any response from other radios. That's very handy when you are always getting connected to the same radio and you want to avoid the manual selection of a preferred one. Very useful also in case you are using scripts for fully automated procedures.

example:

```
>econ -r 00:78:24:22:BA:4F
```

Radio Serial Number

The same functionality as above (see Radio MAC address) can be achieved by providing the radio serial number, instead of the radio physical address. Note that you should not include the initial UC characters of the serial number (i.e. type *11078* instead of *UC11078*)

example:

```
>econ -r 11787
```

Local Physical Address

Even though eConsole identifies the PC local physical address automatically, there are some cases in which the user wants to specify the local address on his/her own. These cases usually arise when there are multiple NIC cards with the same names under WinNT/Win2000 operating system. In such case, the econ might pick up the wrong MAC address, and therefore the user should supply manually the physical address as a command line argument.

example:

```
>econ -m 00:78:24:22:BA:4F
```

Syntax:

econ *<argument list>*

argument list = *argument list* | *argument* | {}

argument = *-o outputfile* | *-i inputfile* | *-r MAC address* | *-a*

Examples

Let's say you want to read a list of commands from the text file called in.txt, and capture the output to a text file called out.txt. You are also interested only in a specific radio with MAC address equal to 00:78:24:22:BA:4F. In that case, you will start the EConsole with the following arguments:

```
>econ -i in.txt -o out.txt -r 00:78:24:22:BA:4F or
```

```
>econ -o out.txt -i in.txt -r 00:78:24:22:BA:4F or
```

>econ -o out.txt -r 00:78:24:22:BA:4F -i in.txt

As you noticed, arguments' order is indifferent. If you don't want to overwrite the contents of the out.txt, in case it already exists, then you can add the *-a* option to indicate that you want to append the captured output to the end of the file.

>econ -o out.txt -r 00:78:24:22:BA:4F -i in.txt -a

If you are reading from the keyboard, and you are simply interested in capturing the output of the session, use the following syntax:

>econ -o out.txt

Since no input file was specified, it is assumed that the keyboard will be used for input, and ALL radios will participate in the discovery process.

Function Keys

Currently there are 5 different function keys.

- input F1 - Online help - gives a short description of the other function keys and the arguments
- F2 - Active/deactivate diagnostic messages. Initially diagnostic messages are not shown, therefore if you want to see them you should press F2. Diagnostic messages include warnings, and retransmission info in order to get an idea of the connection's speed/integrity. Error messages are always shown.
- F3 - Show/hide percentage of input lines been processed. When the econsole is getting the input from a file (instead of the keyboard), showing the percentage of input line being processed gives you an estimation of the remaining time before the whole input file has been read. The default setting is "not shown".
- F4 - Show/hide output to screen. When you don't want to see the output of the commands on the screen, you can press F4. This option usually is combined with the previous feature, so the only information you see on the screen is the current line of the input file. Typically the output is also being captured in an output file, unless you only want to test the integrity of the input file.
- F5 - Reverse/Restore screen settings. Initially the screen displays white letters on black background, but you can reverse it to black letters on a white background.

Commands

The command list is identical to the serial port, with one exception: the *download* command. Let's see first some correct examples with that command.

prompt > download tmp/filename
prompt > download flash/filename

The file with the specific filename must be in the same directory as the *econ.exe*. Also it should NOT have the tmp or flash prefixes. These are used to indicate where to

store the file in the VIP110-24 memory: *tmp* for RAM memory and *flash* for flash PROM.

Example: Let's say you want to download a new release, called *vip01_04.bin*, to the flash memory. Then, you should make sure that the file *vip01_04.bin* is in the same folder as the *econ.exe*, and after starting the EConsole, type the following command:

prompt > download flash/vip01_04

The PC will append automatically the extension *.bin* if the filename is not found on the current directory. If both *filename* and *filename.bin* exist on the working directory, *filename* has priority over the *filename.bin*. Of course, you can force the transfer of the *filename.bin* by specifying the complete name (filename with its extension).

Troubleshooting & Updates

Common problems

1. Failed to open adapter

This usually happens when you haven't installed properly the WinPCap library, or you have an older version of it. Please visit <http://netgroup-serv.polito.it/winpcap/> to get the latest version. You should also make sure that your Ethernet adapters are working properly.

2. Cannot find radio(s) even though they are running properly

Make sure that:

- The ethernet cables are OK
- You are getting connected to the right segment
- You are using the right MAC address. The system tries to identify the adapter physical address through some NetBIOS calls in the Win9X case, or some NDIS queries in the WinNT/Win2000 case. If NetBIOS is not installed, the econ will probably use the wrong local host MAC address. Also if there are more than one Ethernet adapter installed with the same name, this might cause problem in the WinNT/Win2000 case.

Resolution: Use the command line argument to specify the correct physical local address. Example:

>econ -m 00:78:24:22:BA:4F

3. Find a radio but not getting connected

Check if the maximum number of sessions has been reached. The maximum number of sessions on the server side is limited to four, therefore you should NOT connect to the same radio multiple times if not absolutely necessary. When the number of sessions reaches the limit the radio will ignore any new discovery messages.

Another reason might be a unreliable RF link causing a high packet loss. Since during the discovery phase there isn't any retransmission mechanism, it is quite possible that you managed to "see" the radio, but you weren't able to

connect to it, because the connection request packet was lost. In such case, try to connect again.

4. High drop rate - screen freezes momentarily - connection times out

There are two possible causes.

1. The link between the client (PC) and the server (radio) is very weak. If the packet drop rate is more than 20%, then the connection is problematic.
2. There are multiple sessions opened on the same server. With many concurrent sessions the server response may be noticeably slower. Always close the session gracefully by executing the *logout* radio command, and not by closing the MS-DOS console. If the *logout* command is not issued the session at the server will remain open for an additional 15 minutes. Use the *list* command to find out the number of open sessions.

5. If I leave the client inactive for half an hour, and try to type a new command, I get an unable to transfer packet message.

An open session times out after 15 minutes of inactivity. At the end of this time out the server (radio) drops the session. After the client (PC) unsuccessfully attempts several retransmissions it gives up and displays the "unable to transfer packet" error message.

Report a bug & Updates

Please visit <http://www.ucwireless.com/> for more info.

Acknowledgments

The WinPCap library was obtained from "Politecnico di Torino" and the code is distributed in binary form as part of the Econsole. The following copyright notice applies to that library.

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